Soil Composite Mapping Processor (SCMaP) product suite as EO soil monitoring data base - potential and challenges

Simone Zepp, Marianne Jilge, Annekatrin Metz-Marconcini, Mattia Marconcini, Uta Heiden

German Aerospace Center (DLR) Oberpfaffenhofen
Dynamic of Land Surface

Introduction

Continental to global soil mappings

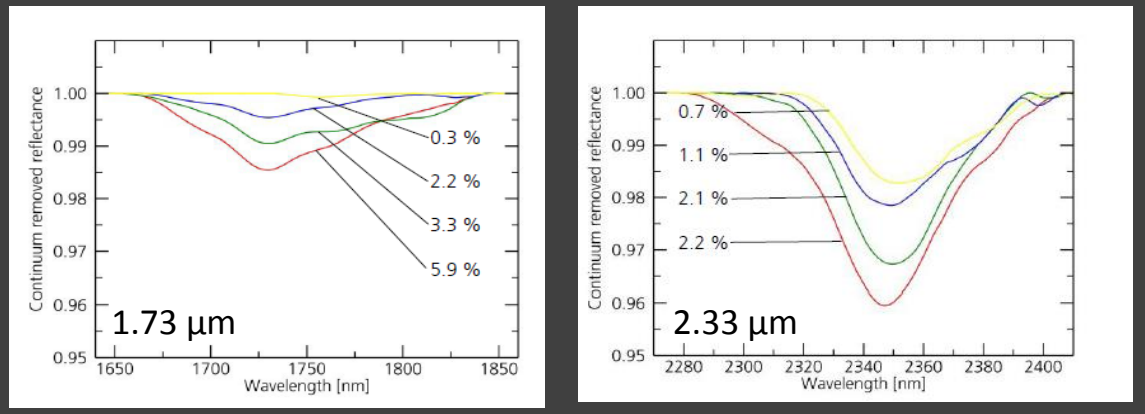
Name	Scale	Owner/Creator	Comments
Soil Map of the World	**1:5 000 000**	FAO/UNESCO	First global soil data base
Harmonized World Soil Database	30 arc-second raster database	FAO, IIASA, ISRIC, ISSCAS, JRC	Combines regional + national soil info updates and Soil Map of the World
World Resource Base Map	1:25 000 000	FAO, EC ISRIC	International collaboration coordinated by the IUSS Working Group; using the original soil map of the world as basis
World Soil Regions	1:5 000 000	FAO/UNESCO	based on the Soil Map of the World but uses the USDA Soil Taxonomy.
European Soil Database & soil properties	1:1 000 000 10 km x 10 km 1 km x 1 km	JRC	dates back to the 1990

- Generation based on point-based (soil profiles) and area-based (climate, terrain, LC/LU, vegetation dynamics, …)
- Optical EO data so far on MERIS / MODIS scale (300 m pixel size)

Introduction

Optical EO for soil monitoring - challenges

- Information about spatial variability is underrepresented
- Imaging spectroscopy allows for direct quantification of soil constituents - Data not available for large areas
- Spectral resolution of multispectral data (Landsat / Sentinel-2) not sufficient for direct quantification
- Soils exposure is rare and variable in time
- Information about soil development is missing on large scale



Soil Organic Carbon Absorptions in imaging spectroscopy data continuum removed; Source: M. Bachmann)

Loss of A and B horizons due to erosion in Spain

Introduction

Optical EO for soil monitoring - challenges

- Information about spatial variability is underrepresented
- Imaging spectroscopy allows for direct quantification of soil constituents - Data not available for large areas
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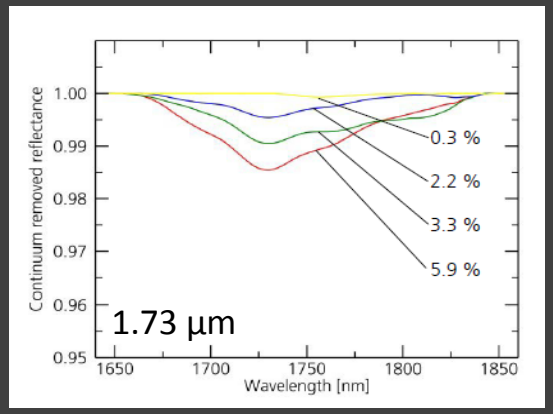
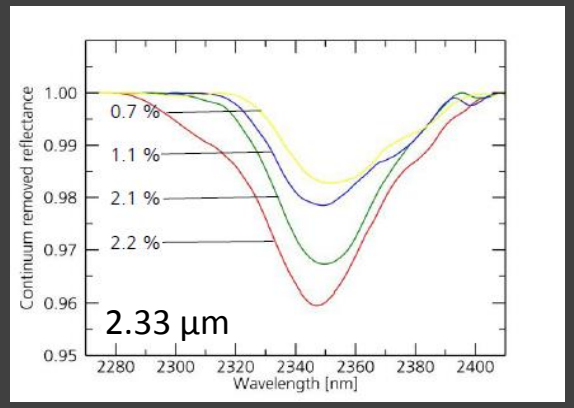




Soil Organic Carbon Absorptions in imaging spectroscopy data continuum removed; Source: M. Bachmann)

Exploration of multispectral data archives

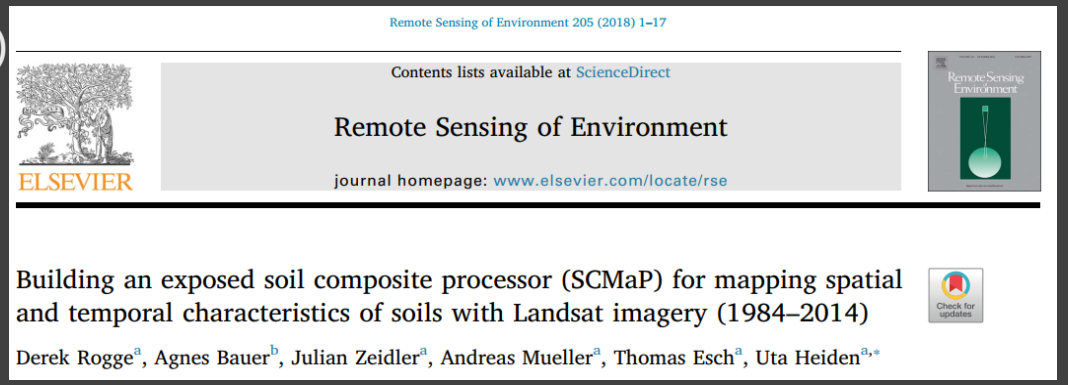

remote sensing

MDPI

Article

Barest Pixel Composite for Agricultural Areas Using Landsat Time Series

Sanne Diek *, Fabio Fornallaz, Michael E. Schaepman and Rogier de Jong


Remote Sensing of Environment 205 (2018) 1–17

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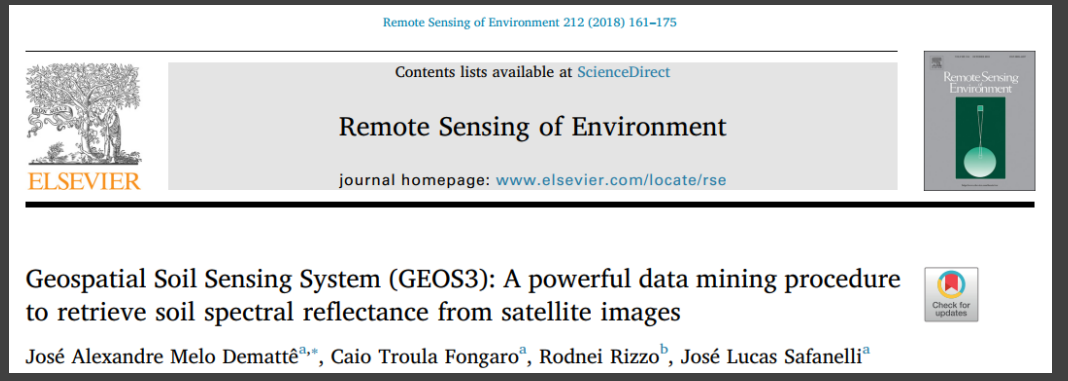
journal homepage: www.elsevier.com/locate/rse

ELSEVIER

Building an exposed soil composite processor (SCMaP) for mapping spatial and temporal characteristics of soils with Landsat imagery (1984–2014)

Derek Rogge[a], Agnes Bauer[b], Julian Zeidler[a], Andreas Mueller[a], Thomas Esch[a], Uta Heiden[a,*]


Remote Sensing of Environment 212 (2018) 161–175

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ELSEVIER

Geospatial Soil Sensing System (GEOS3): A powerful data mining procedure to retrieve soil spectral reflectance from satellite images

José Alexandre Melo Demattê[a,*], Caio Troula Fongaro[a], Rodnei Rizzo[b], José Lucas Safanelli[a]

Introduction

Soil Composite Mapping Processor (SCMaP) – main idea

Soil exposure vary over time (example RapidEye, 2012)

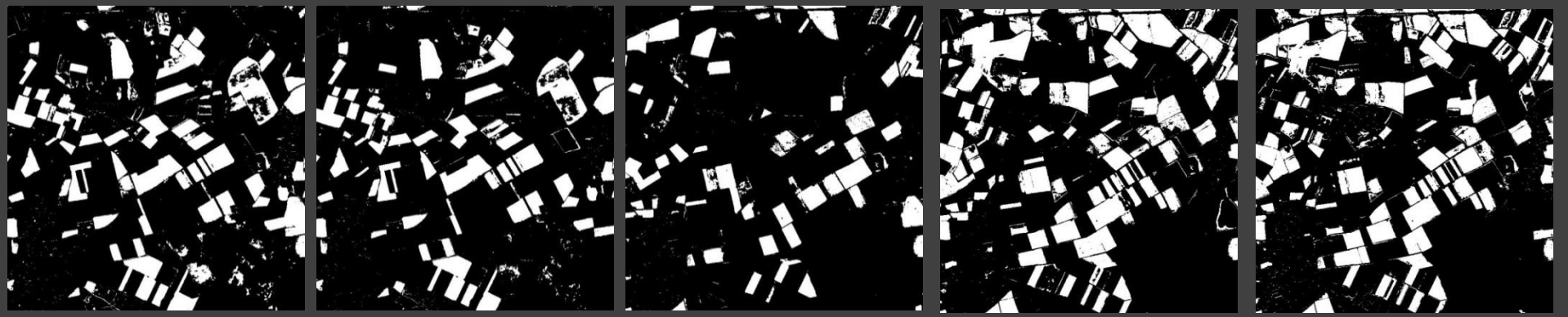
April
20.5 %

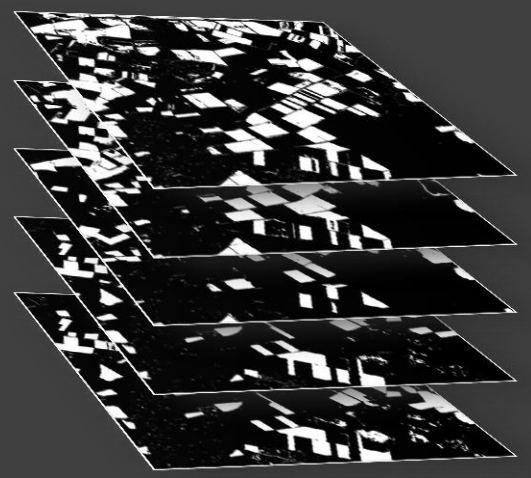
May
17.5 %

July
13.8 %

August
26.8 %

September
25.8 %





Expanding data base
Bare Soil Exposure = 47.9 %

SCMaP

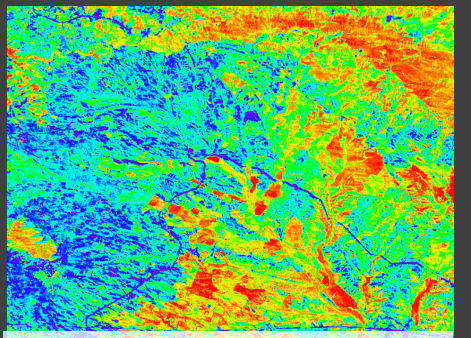
Product suite for soil monitoring

Soil Reflectance Composites

Soil Reflectance Composite

Soil Reflectance Composite (Normalised)

Mean Albedo



No. of Valid Inputs

SCMaP

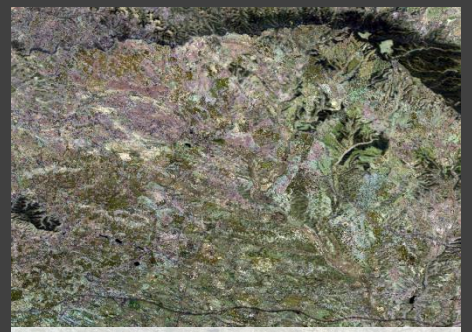
Product suite for soil monitoring

Soil Reflectance Composites

Additional Information on Land Cover Dynamics

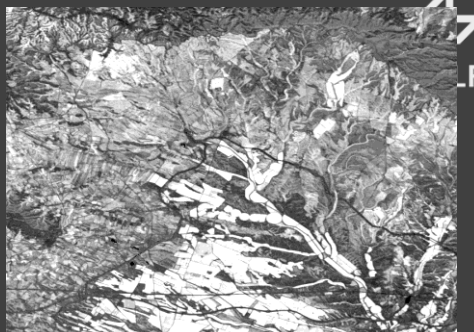
Statistics

Reflectance Comp. (Maximum Index)



Reflectance Comp. (Minimum Index)

Reflectance Comp. (Mean)

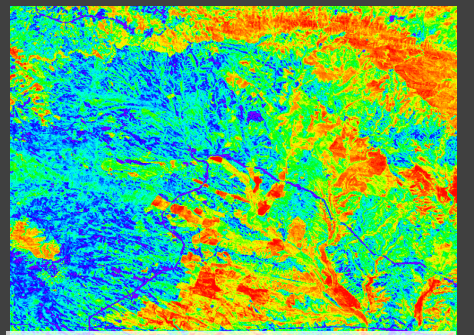


Index Composite (Stats)

Soil Reflectance Composite

Soil Reflectance Composite (Normalised)

Mean Albedo



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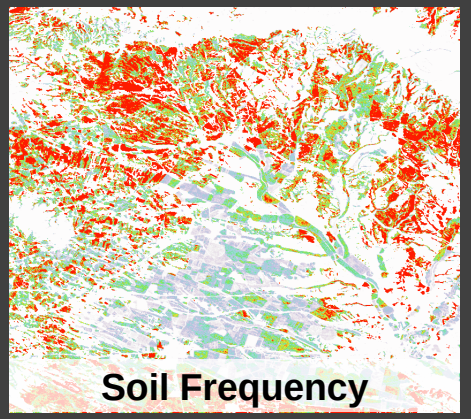
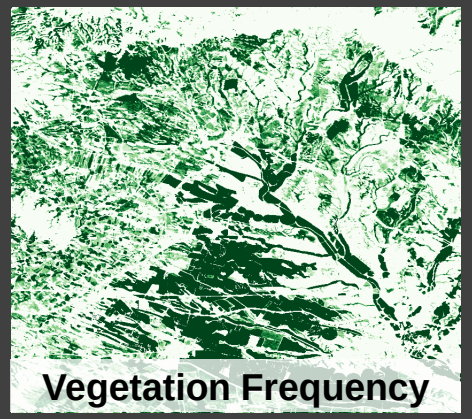
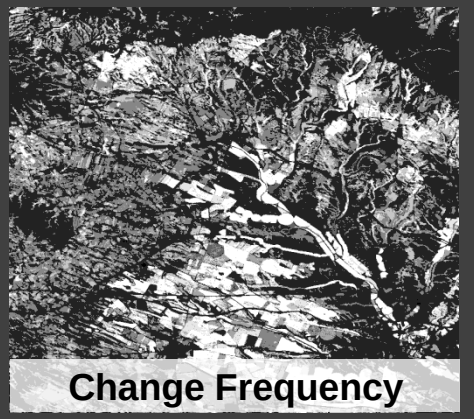


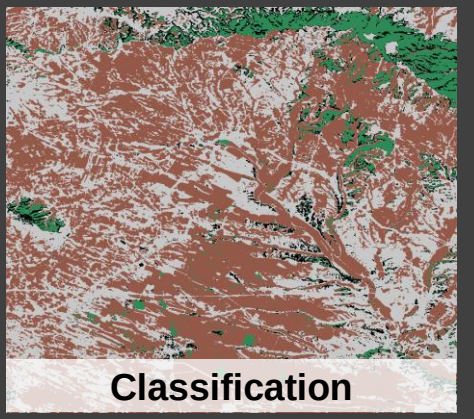
Soil Frequency



Vegetation Frequency



Change Frequency



Classification

SCMaP

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Additional Information on Land Cover Dynamics

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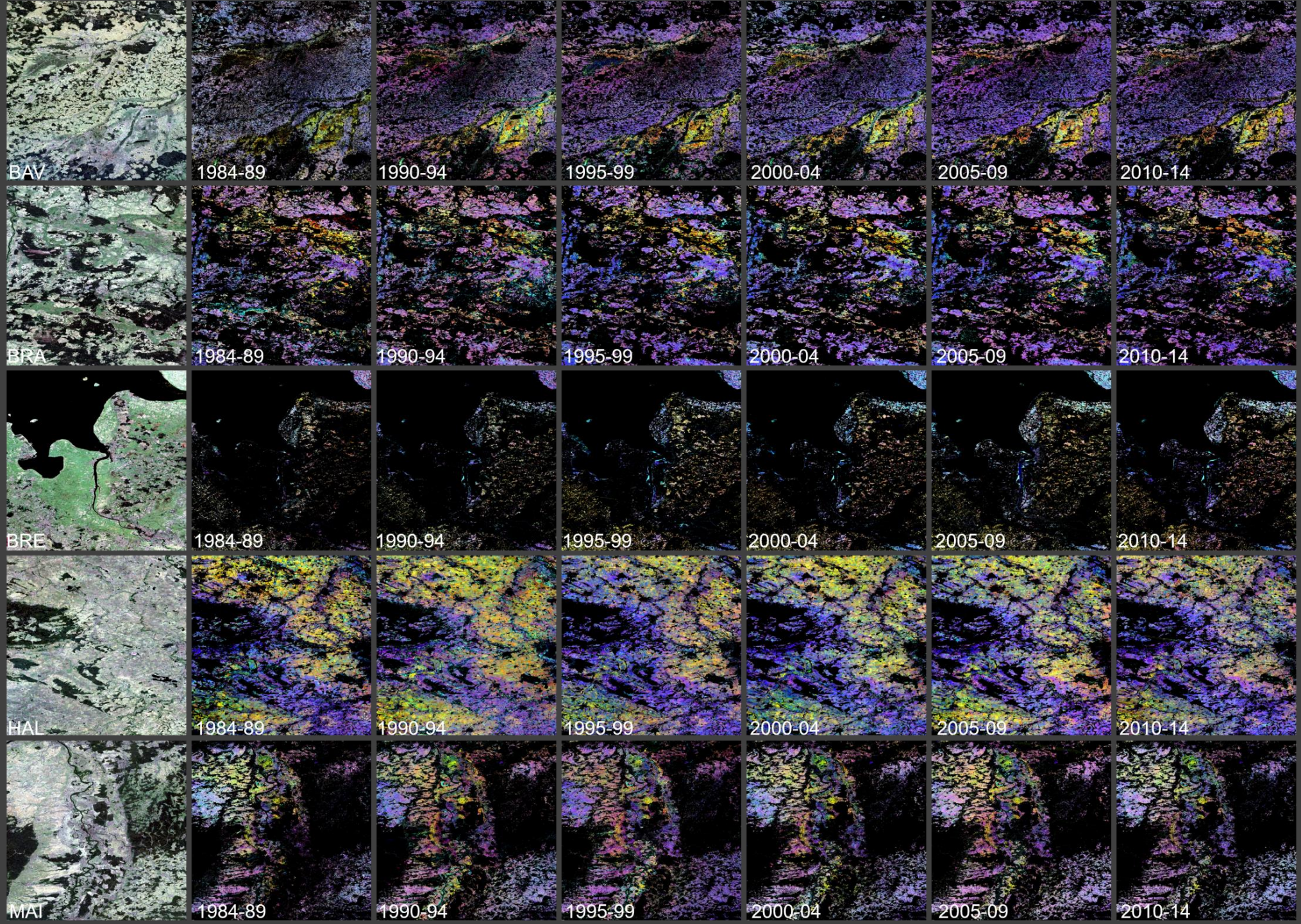
Products available for different time periods



SCMaP

Product suite for soil monitoring

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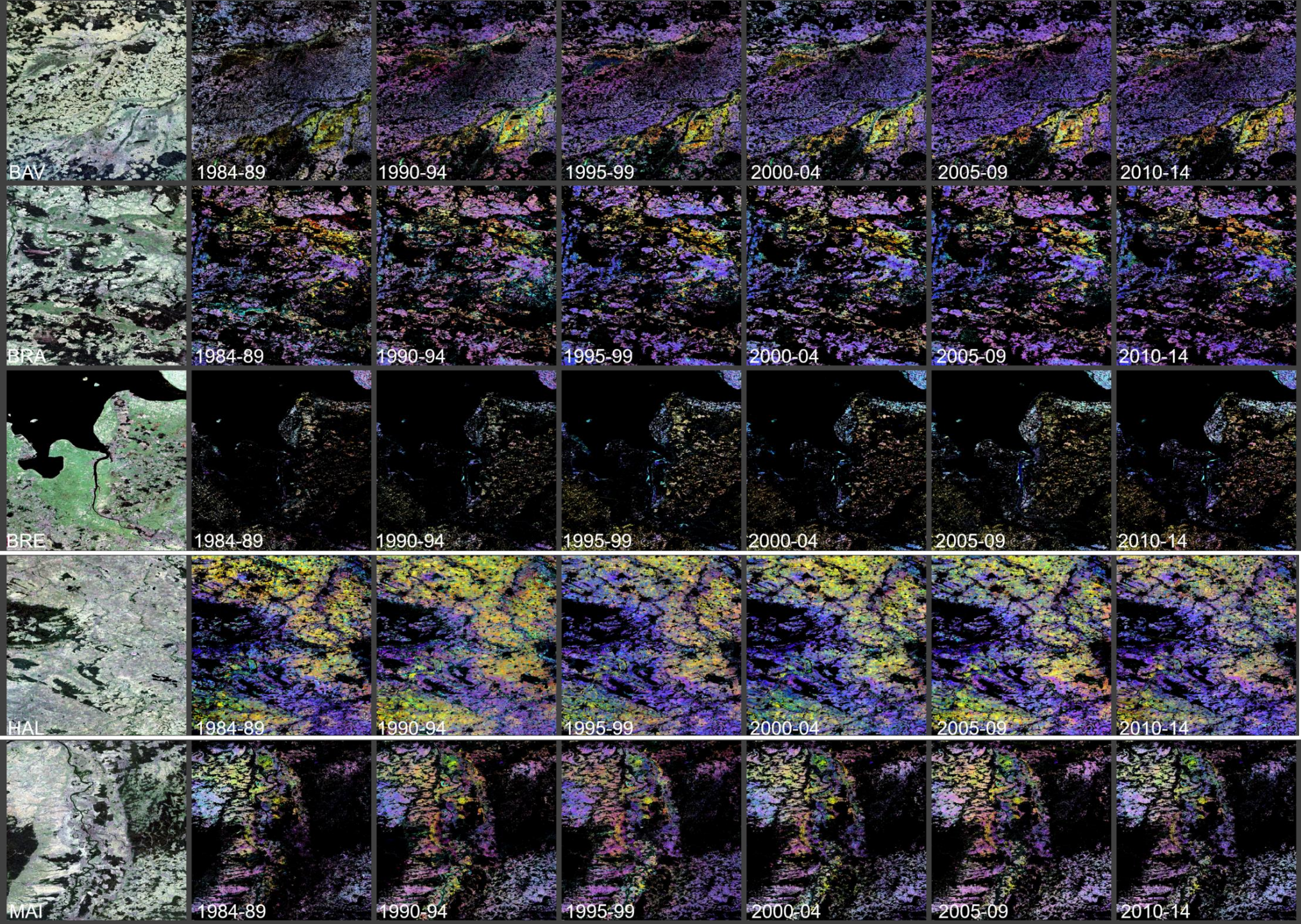
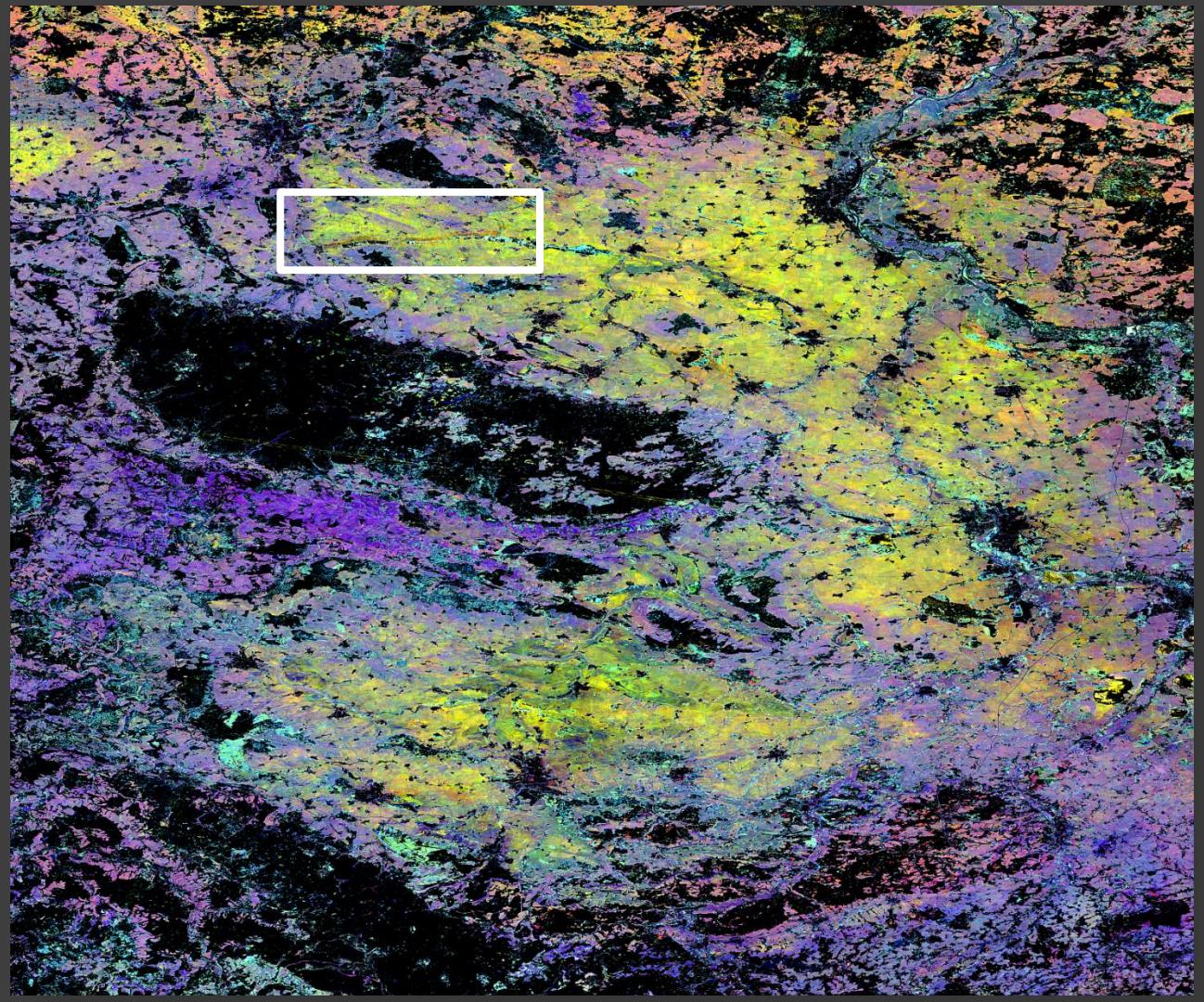
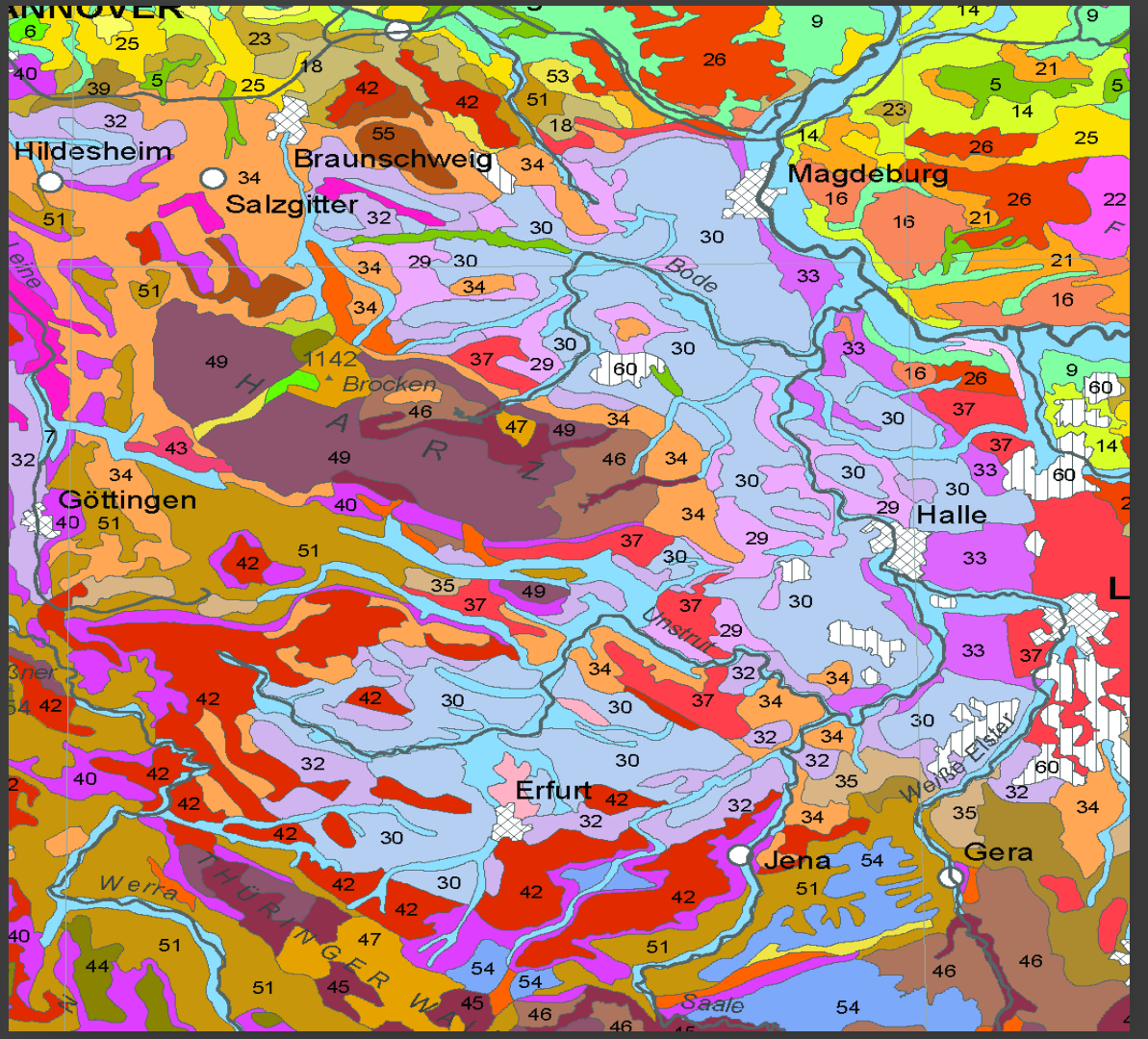


SCMaP

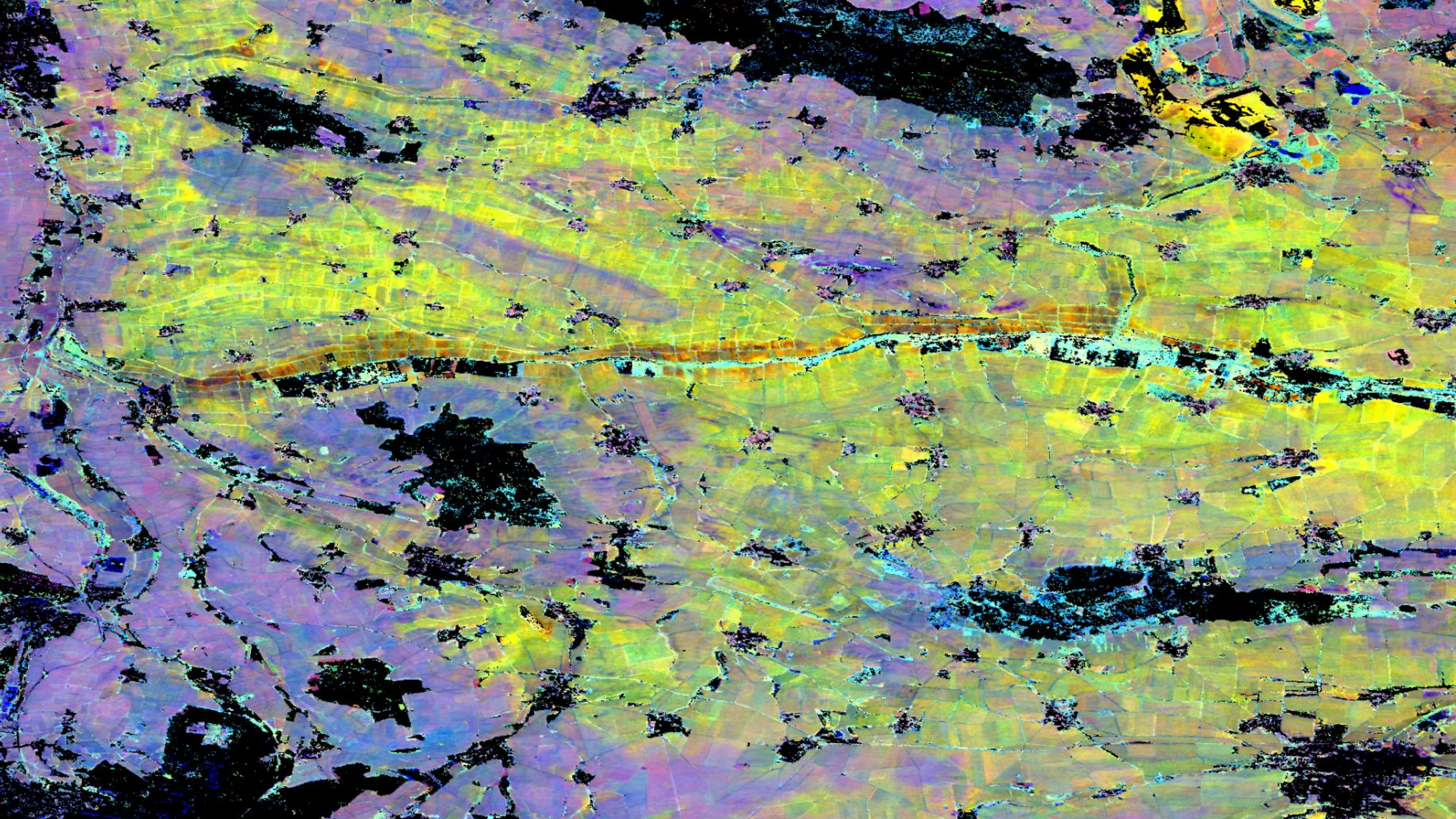
Product suite for soil monitoring



Around Harz Mountains, Germany

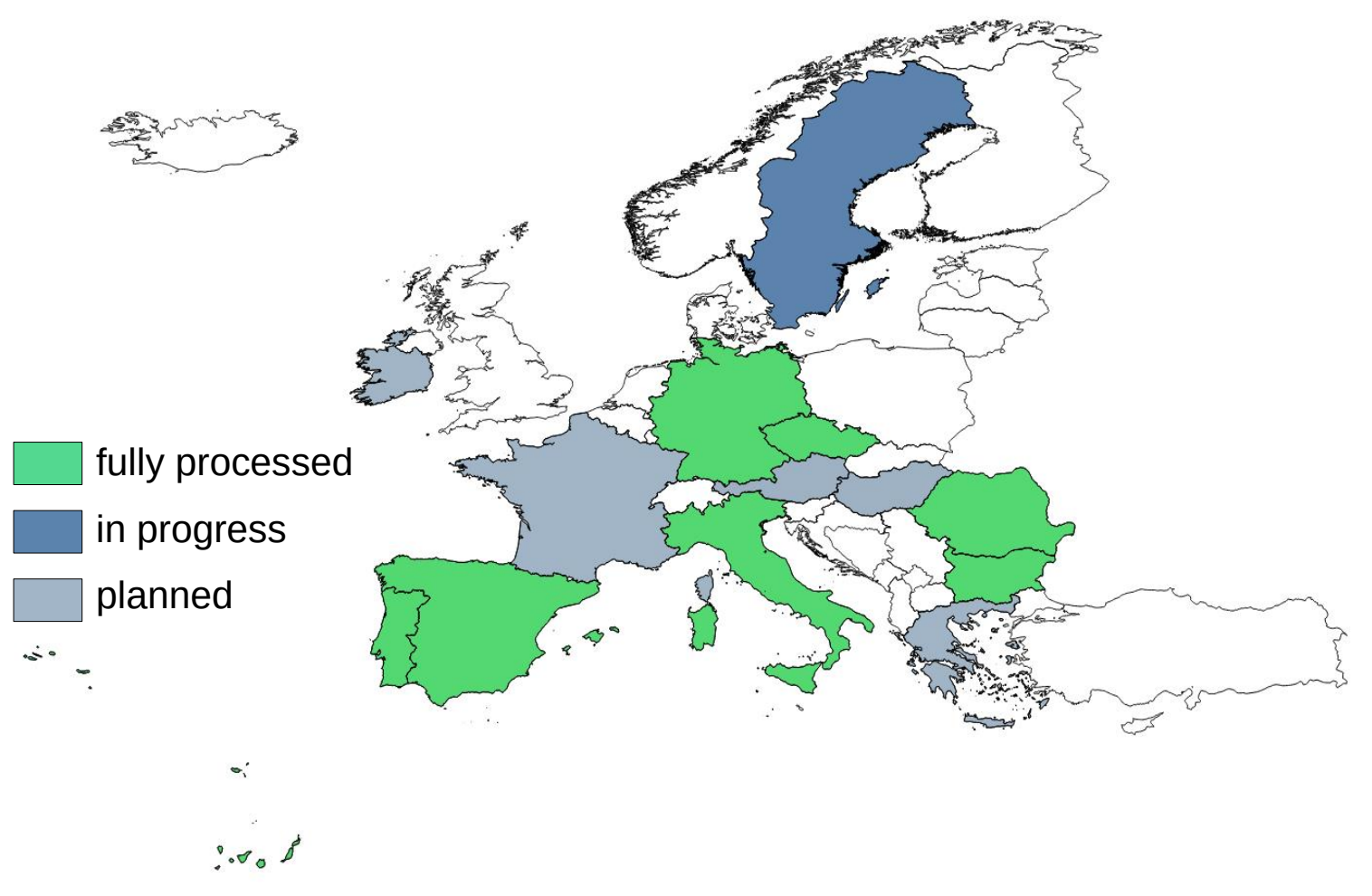


BÜK 1000 - Soil Map of Germany



SCMaP

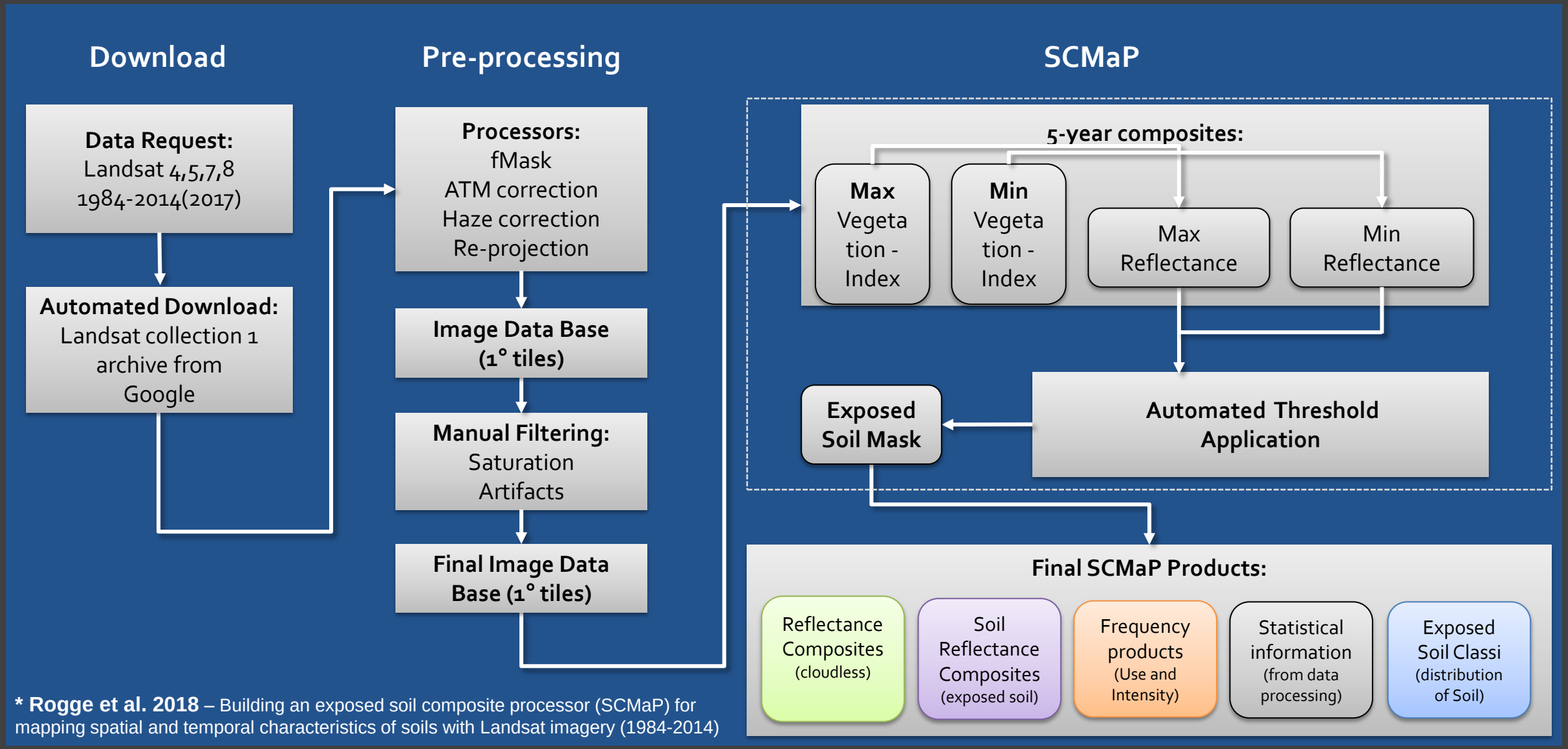
Current SCMaP processing status



Country	Downloaded	Pre-processed
Germany	20,318	11,438
Bulgaria	5,561	5,383
Romania	9,550	8,915
Czech Republic	3,260	2,943
Iberian Peninsula	18,938	18,755
Italy	16,067	12,434
Sweden	12,453	proc.
Greece	proc.	proc.
Ireland	proc.	proc.
France	proc.	proc.

SCMaP

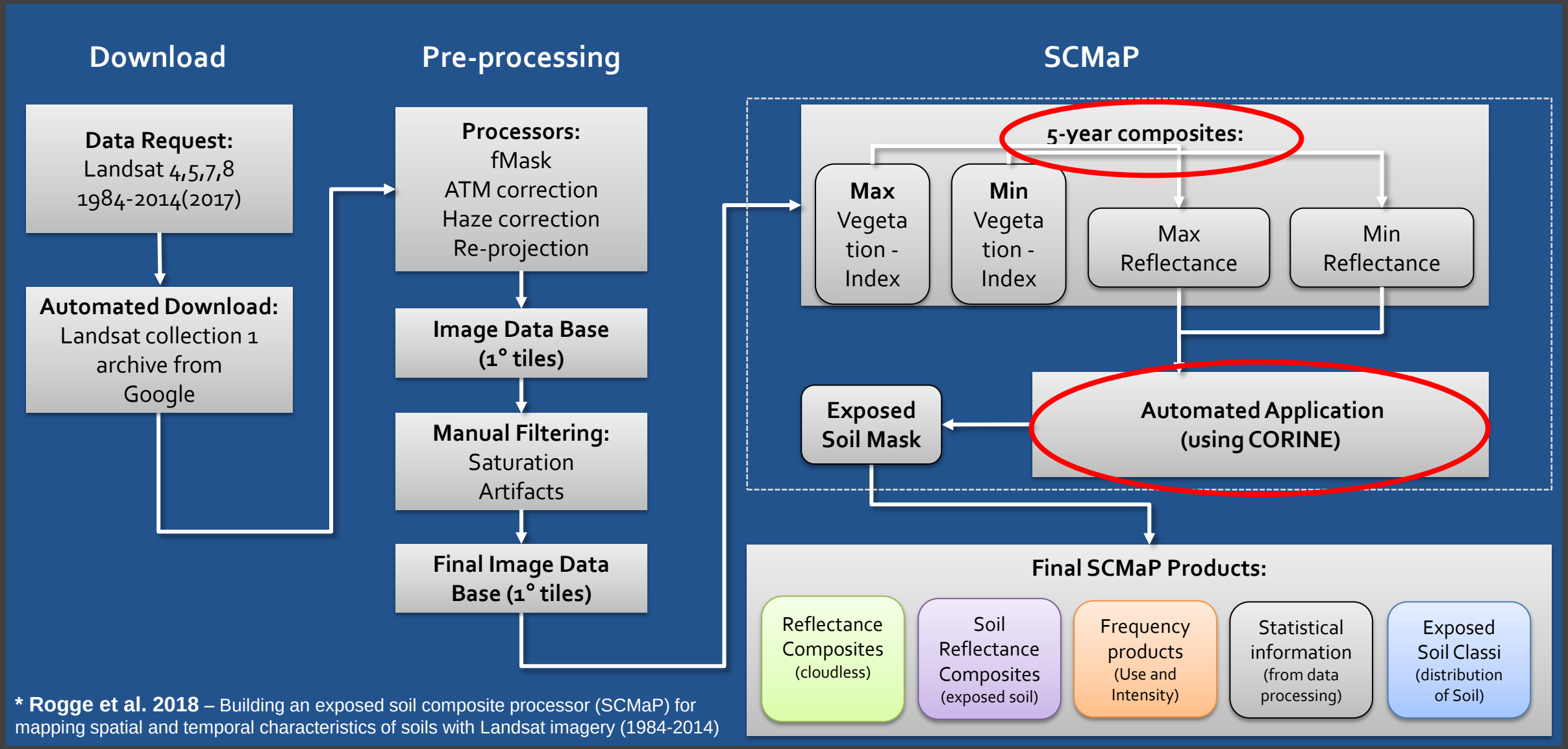
End-to-End SCMaProcessor - overview



*** Rogge et al. 2018** – Building an exposed soil composite processor (SCMaP) for mapping spatial and temporal characteristics of soils with Landsat imagery (1984-2014)

SCMaP

End-to-End SCMaProcessor - overview



*** Rogge et al. 2018** – Building an exposed soil composite processor (SCMaP) for mapping spatial and temporal characteristics of soils with Landsat imagery (1984-2014)

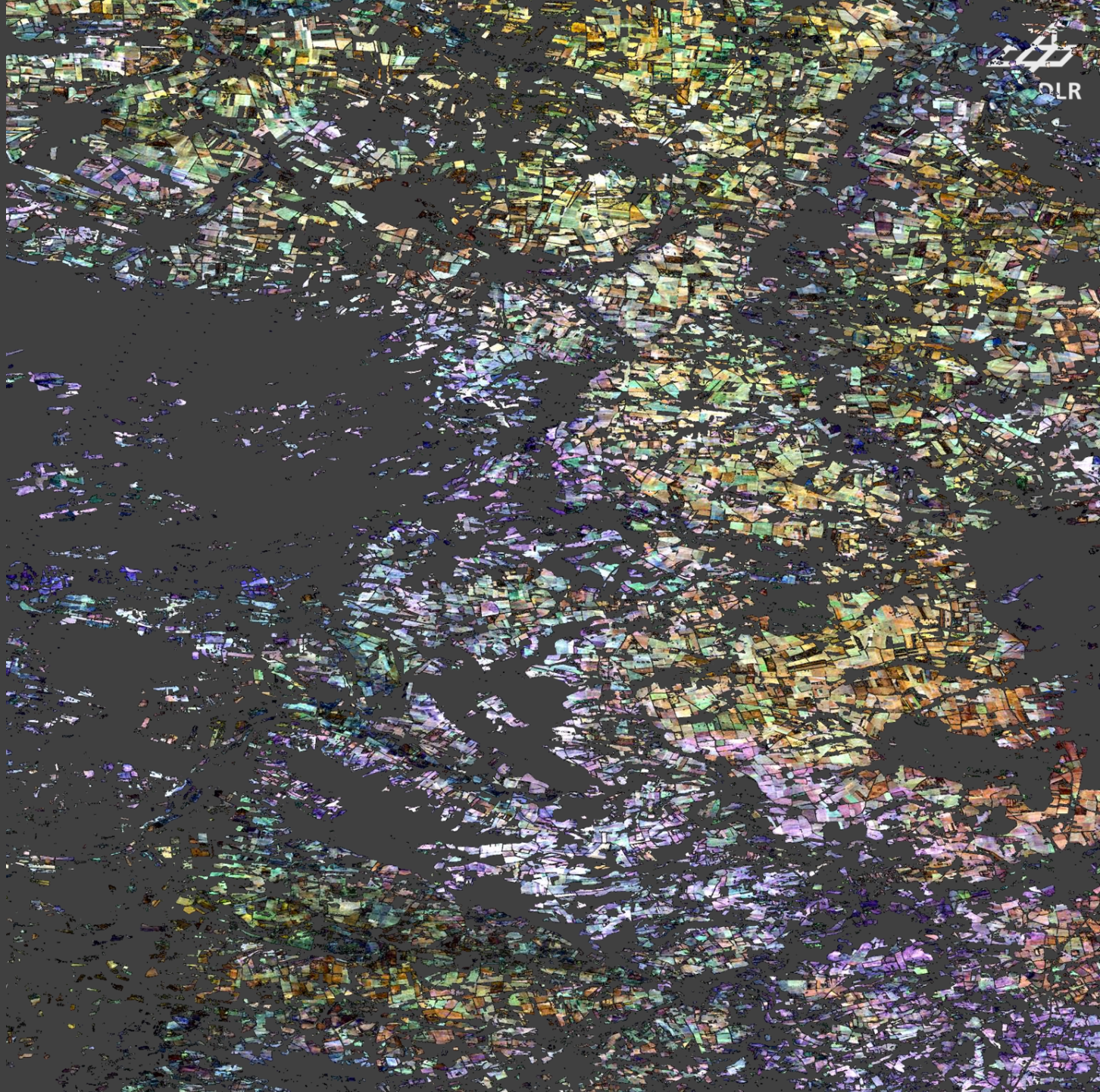
SCMaP

Compositing

1 Year

Influencing factors to define the time period:

- Data availability (clouds, L7 striping)
- Spectral variability
  - Soil moisture / climatic conditions
  - Cultivation
- Real soil changes
  - Erosion
  - Climate impact
- Purpose of analysis



SCMaP

Compositing

2 Years

Influencing factors to define the time period:

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- Real soil changes
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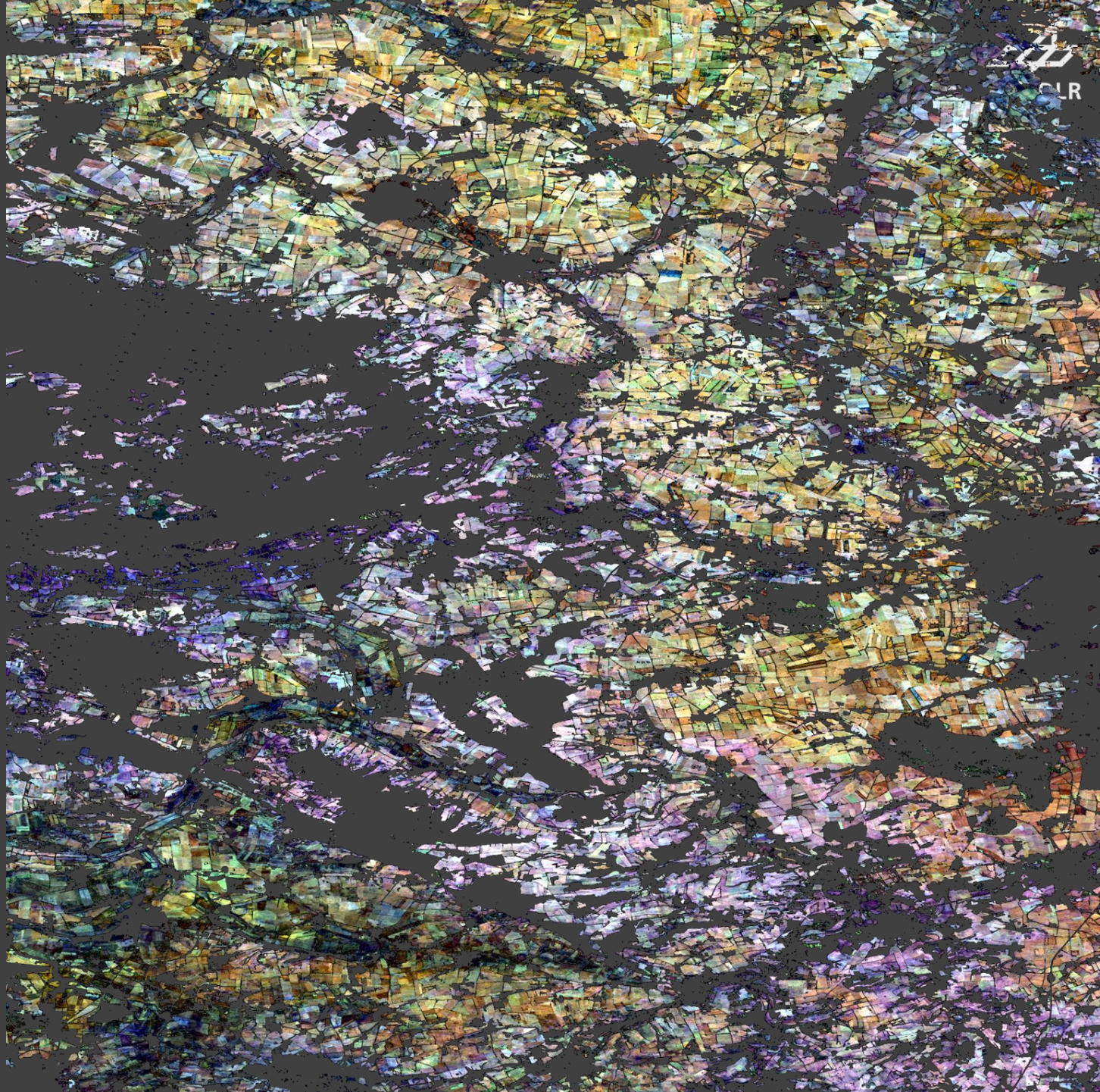


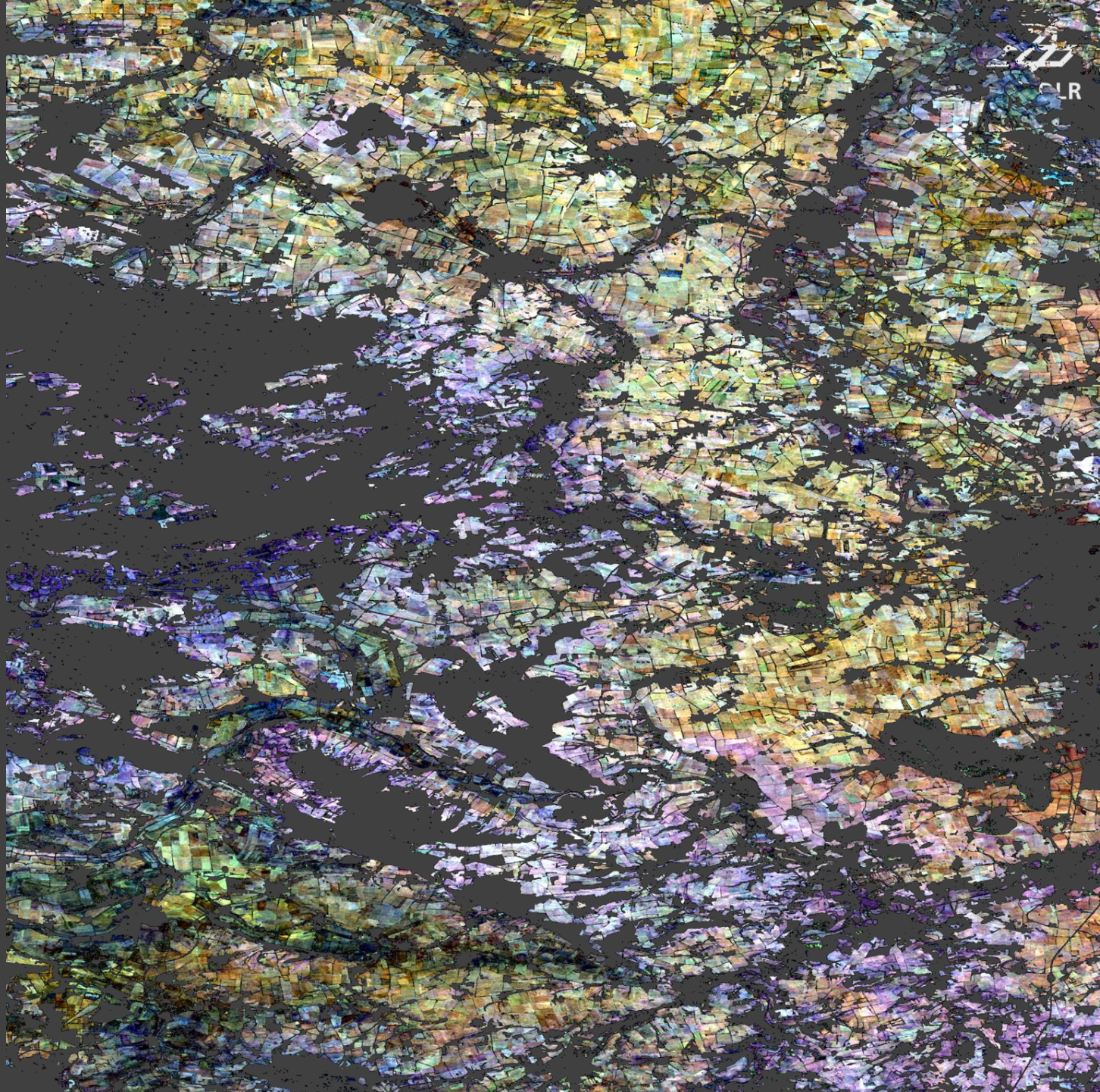
SCMaP

Compositing

3 Years

Influencing factors to define the time period:

- Data availability (clouds, L7 striping)
- Spectral variability
  - Soil moisture / climatic conditions
  - Cultivation
- Real soil changes
  - Erosion
  - Climate impact
- Purpose of analysis



SCMaP

Compositing

5 Years

Influencing factors to define the time period:

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  - Cultivation
- Real soil changes
  - Erosion
  - Climate impact
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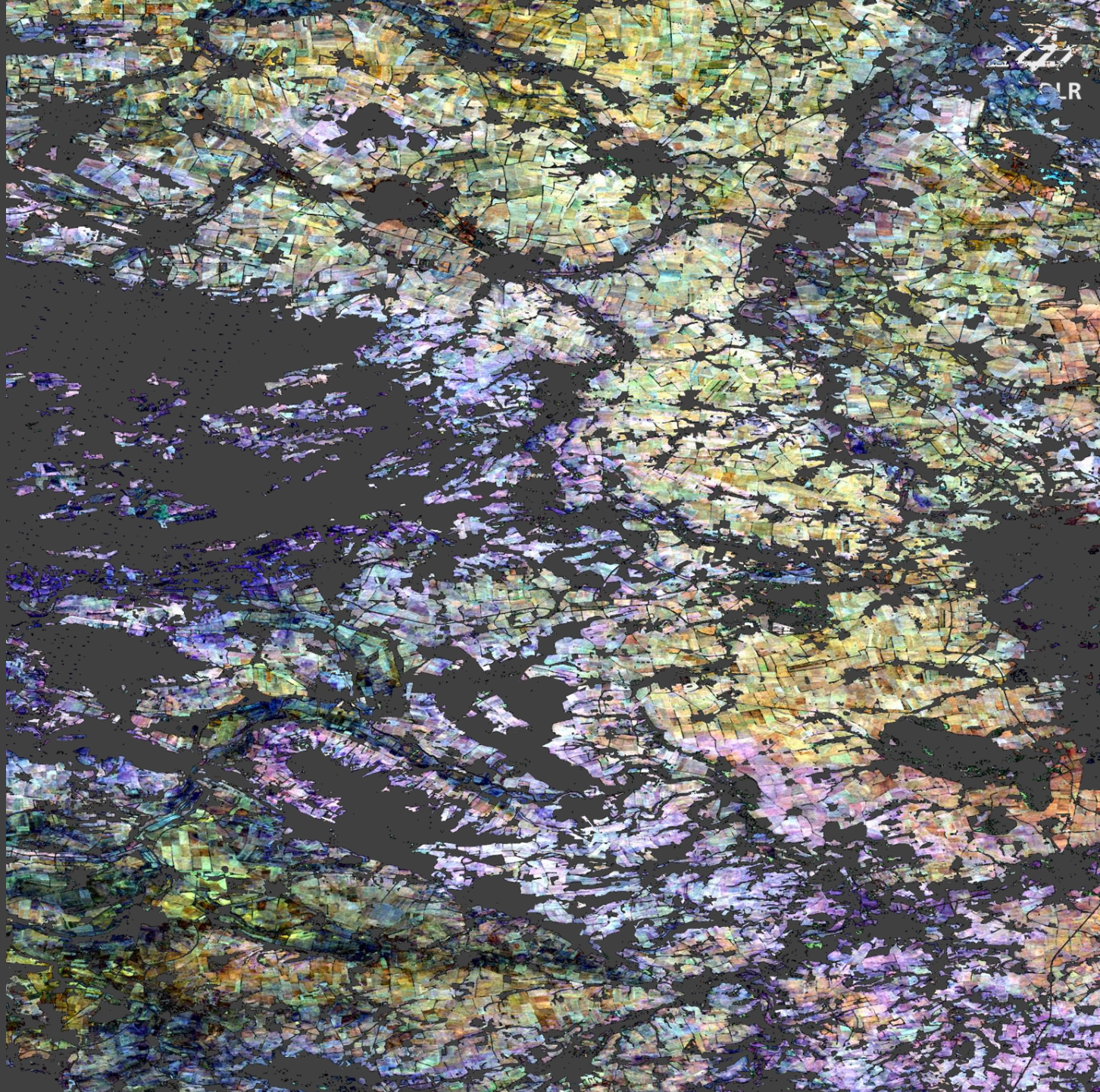

SCMaP

Compositing

10 Years

Influencing factors to define the time period:

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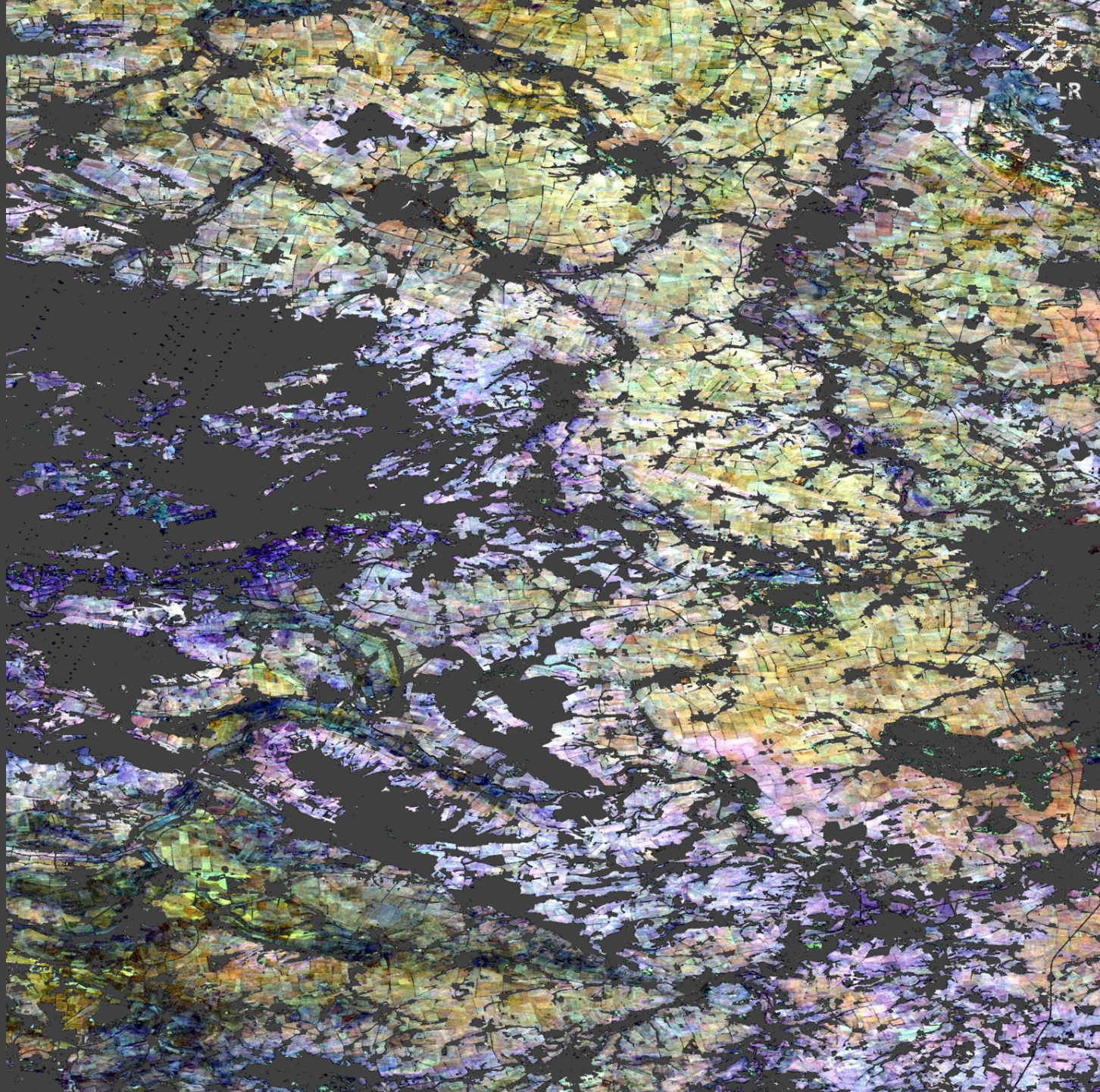

SCMaP

Compositing

15 Years

Influencing factors to define the time period:

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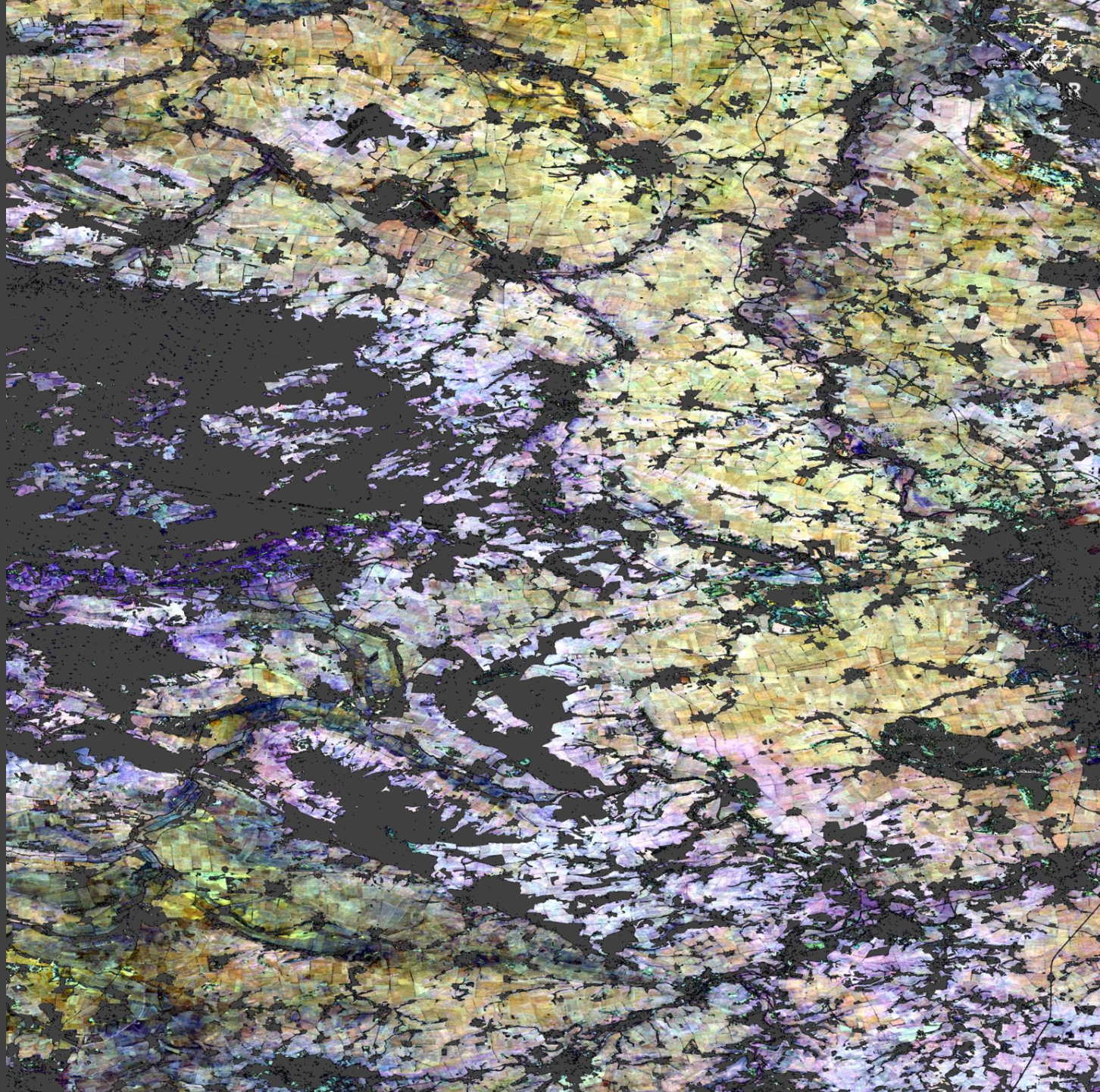


SCMaP

Automated threshold setting

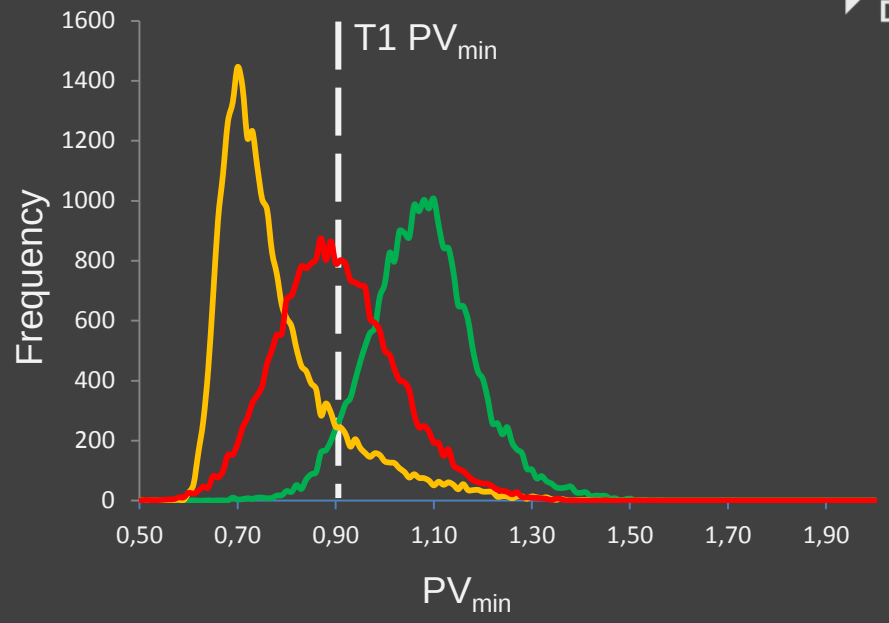
Challenges using multispectral data:

- Separating exposed soils from all other land covers
- Spectral ambiguities with urban areas and non-photosynthetic vegetation

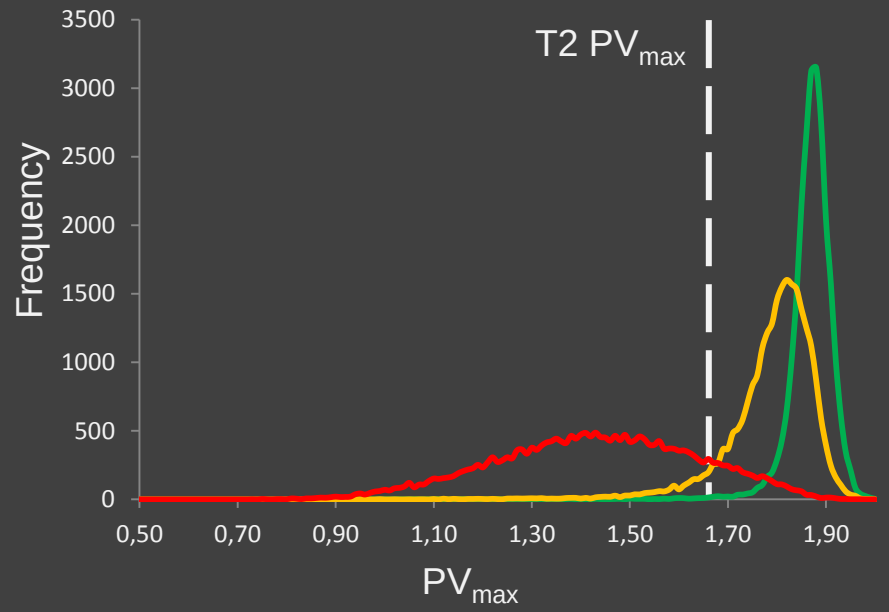
Solution:

- Based on Vegetation index $\text{PV Index} = \frac{NIR-RED}{NIR+RED} + \frac{NIR-BLUE}{NIR+BLUE}$
- Use of seasonal reflectance characteristics of:
  - Agricultural areas
  - Urban areas
  - Deciduous trees / Grassland
- Landcover type selection based on CORINE
- Analysis across country and across time

PV_{Min} composites per time period



PV_{Max} composites per time period



SCMaP

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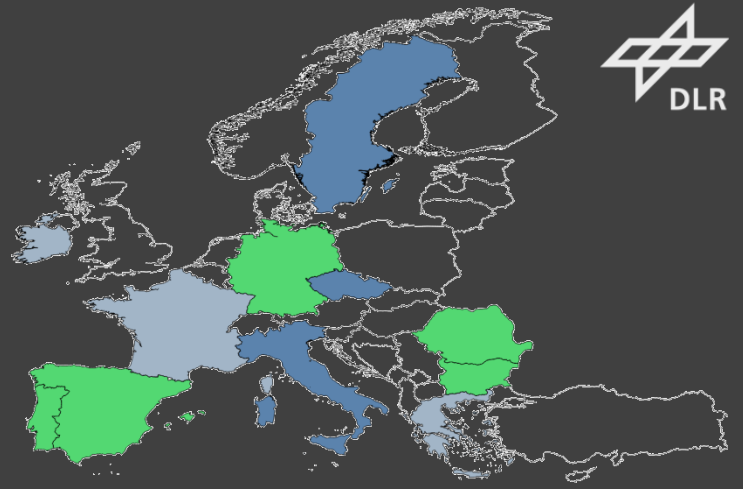

- Iterative analysis of threshold characteristics
  - Across Europe (transects)
  - Across time
  - Number of pixels per LC class

Analysis/ Influence	Result
Spatial variance (tiles/country)	data-driven (dependent on land cover)
Temporal variance (5-year composites)	relatively stable
No of selected pixels (absolute/percentage)	no significant threshold differences

SCMaP

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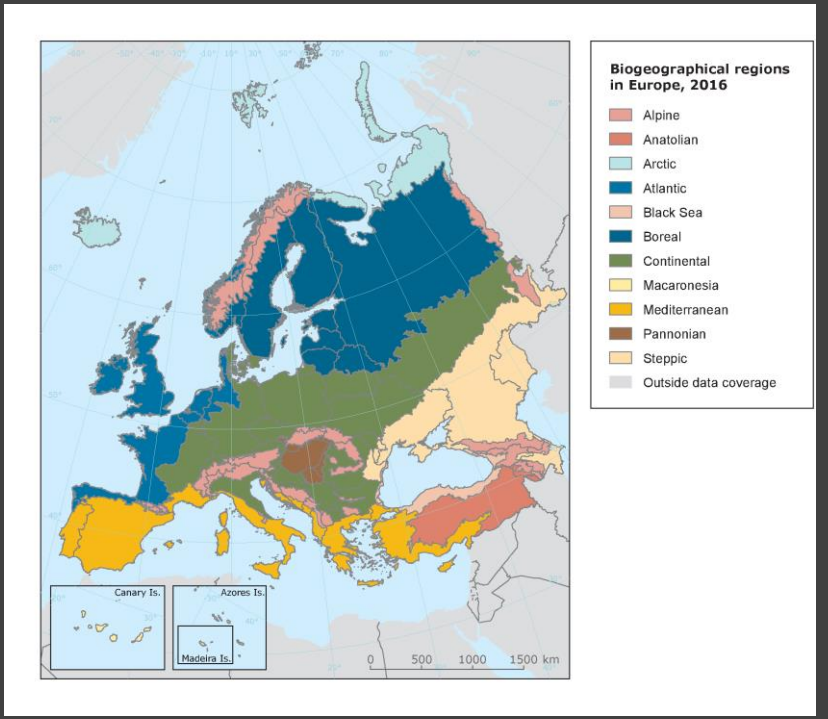
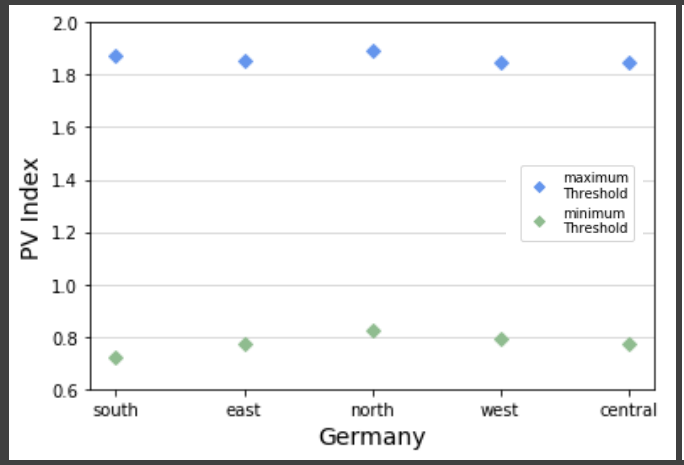
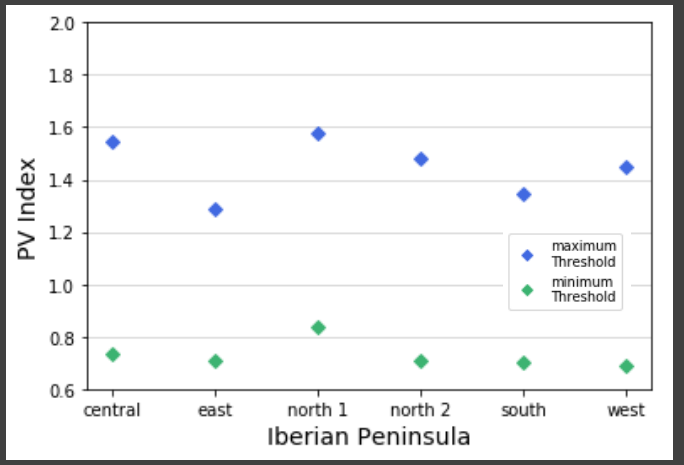


Spatial distribution





SCMaP

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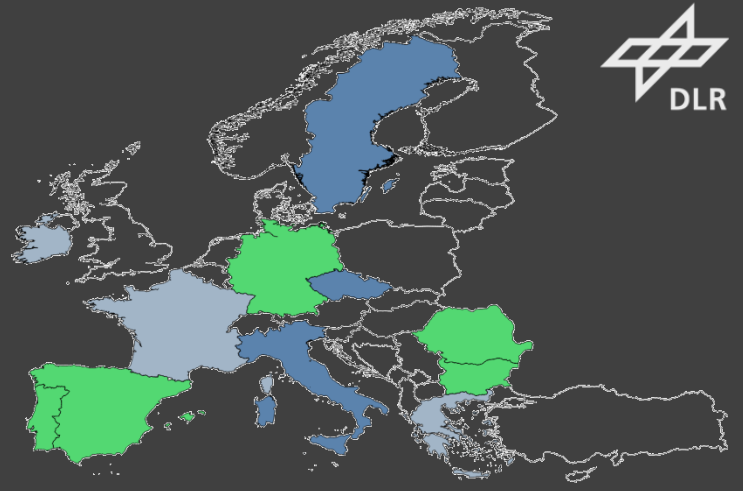

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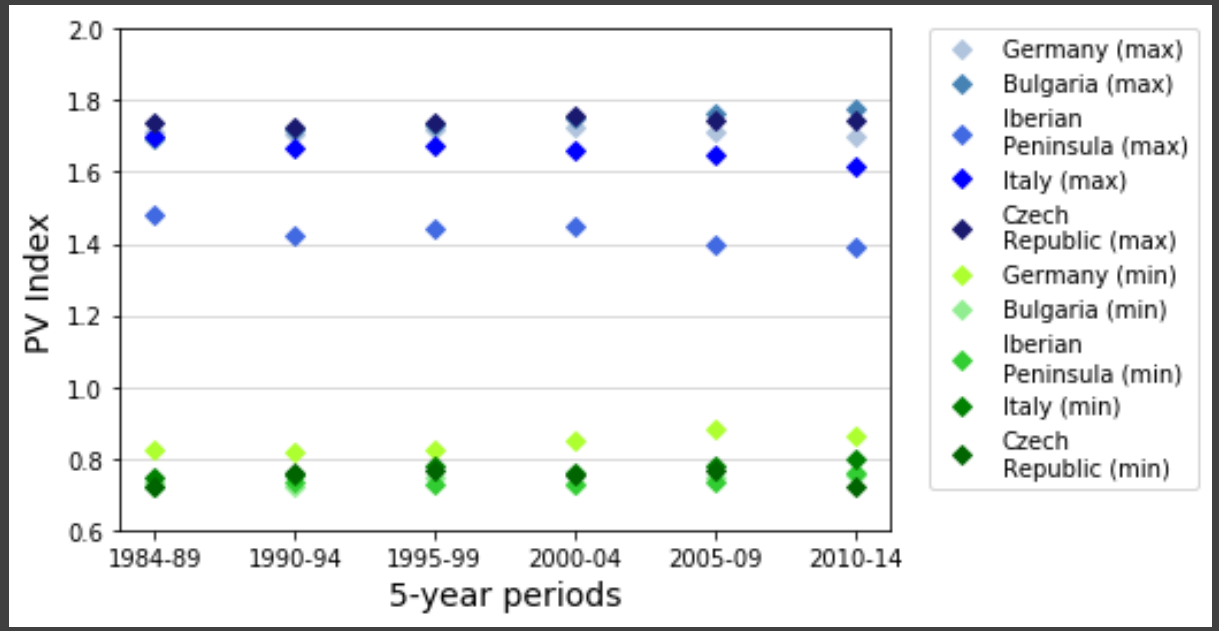
Temporal variance



SCMaP

Automated threshold setting

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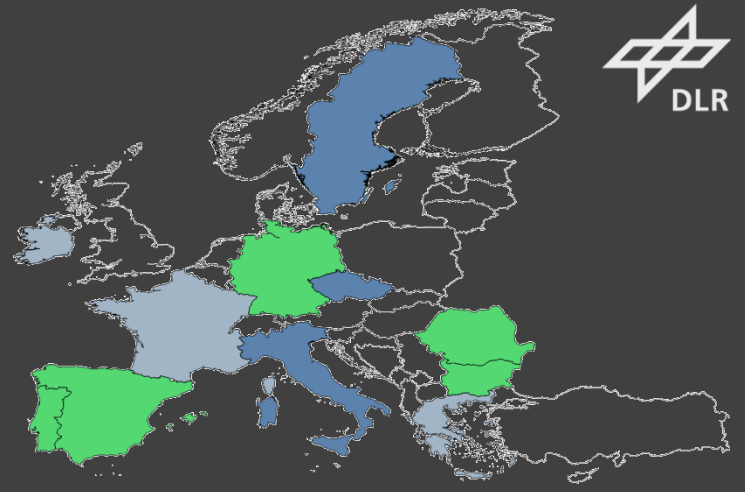

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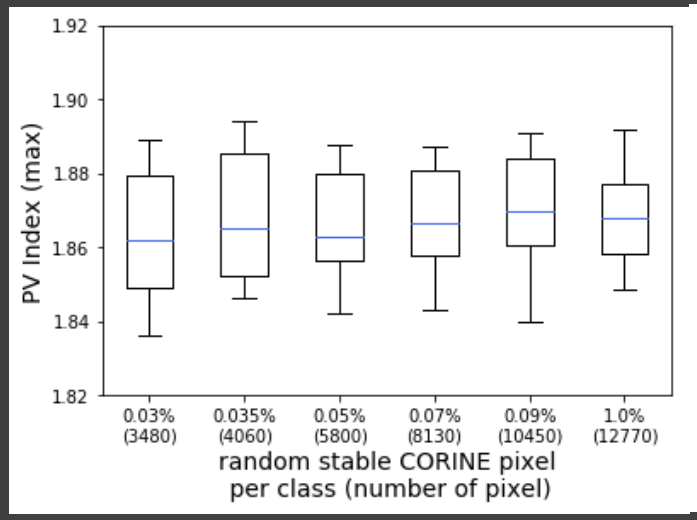
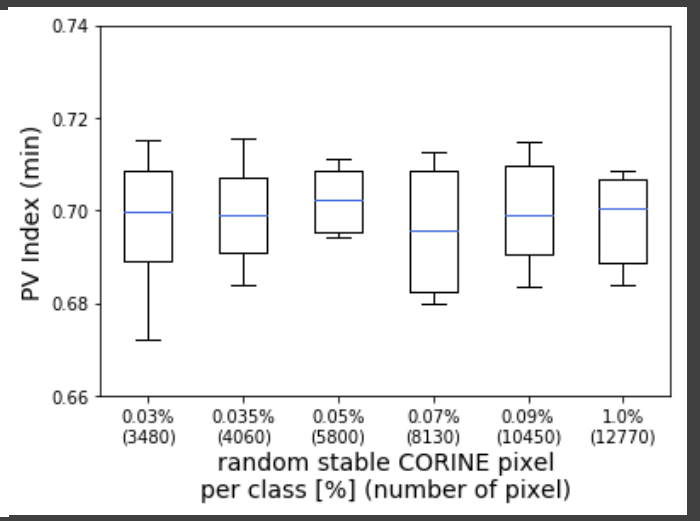
Amount of selected pixels





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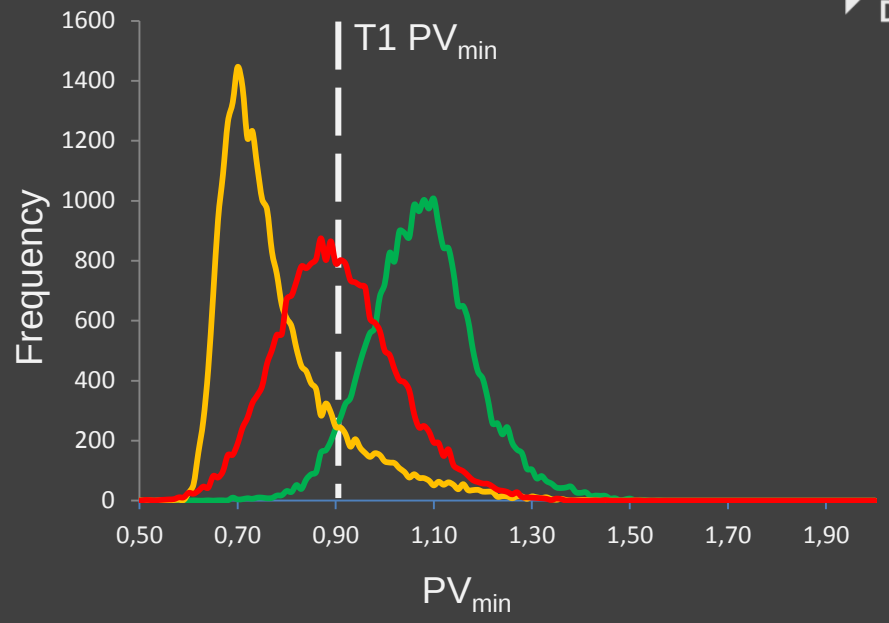
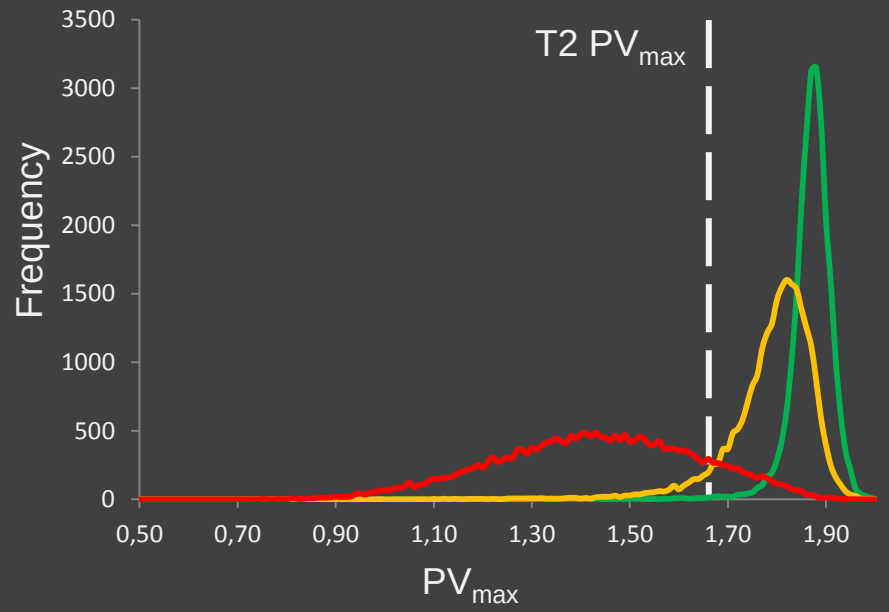
Solution:

- Based on Vegetation index $\text{PV Index} = \frac{NIR-RED}{NIR+RED} + \frac{NIR-BLUE}{NIR+BLUE}$
- Use of seasonal reflectance characteristics of:
  - Agricultural areas
  - Urban areas
  - Deciduous trees / Grassland
- Landcover type selection based on CORINE
- Analysis across country and across time

PV_{Min} composites per time period



PV_{Max} composites per time period



SCMaP

Automated threshold setting

Challenges using multispectral data:

- Separating exposed soils from all other land covers
- Spectral ambiguities with urban areas and non-photosynthetic vegetation

Solution:

- Based on Vegetation index $\text{PV Index} = \frac{NIR-RED}{NIR+RED} + \frac{NIR-BLUE}{NIR+BLUE}$
- Use of seasonal reflectance characteristics of:
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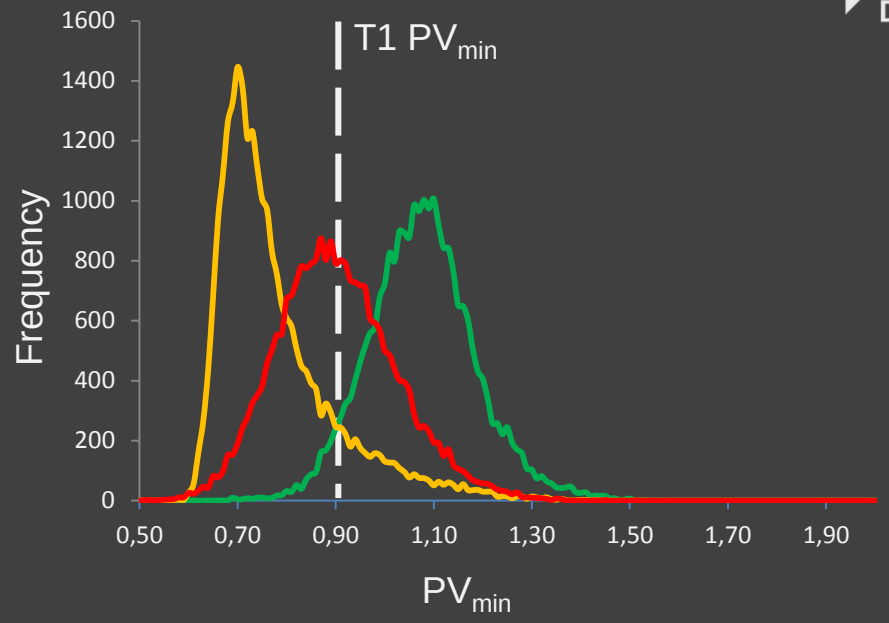
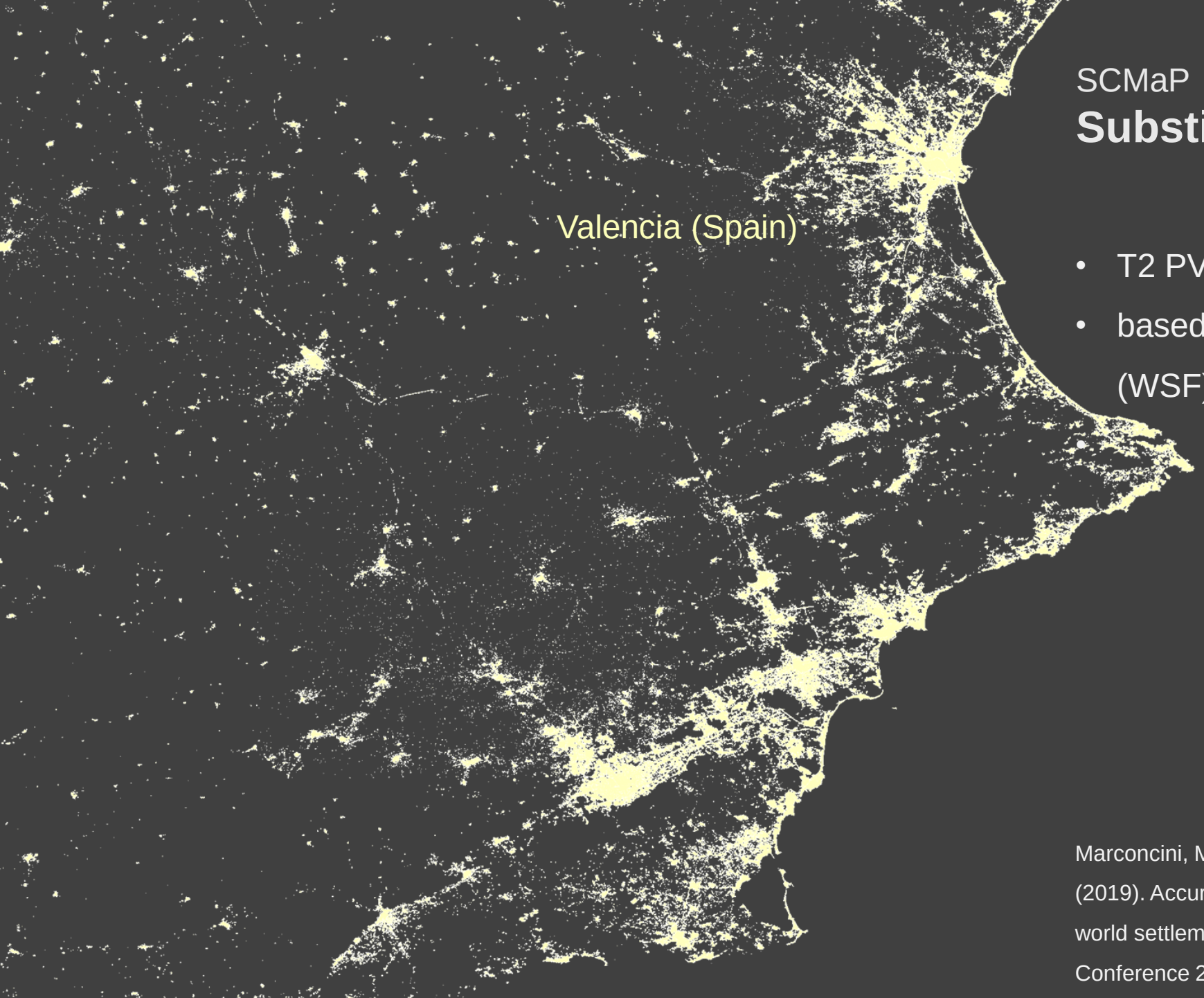
PV_{Min} composites per time period



Substitution of T2 PV_{max} using an urban settlement mask



SCMaP

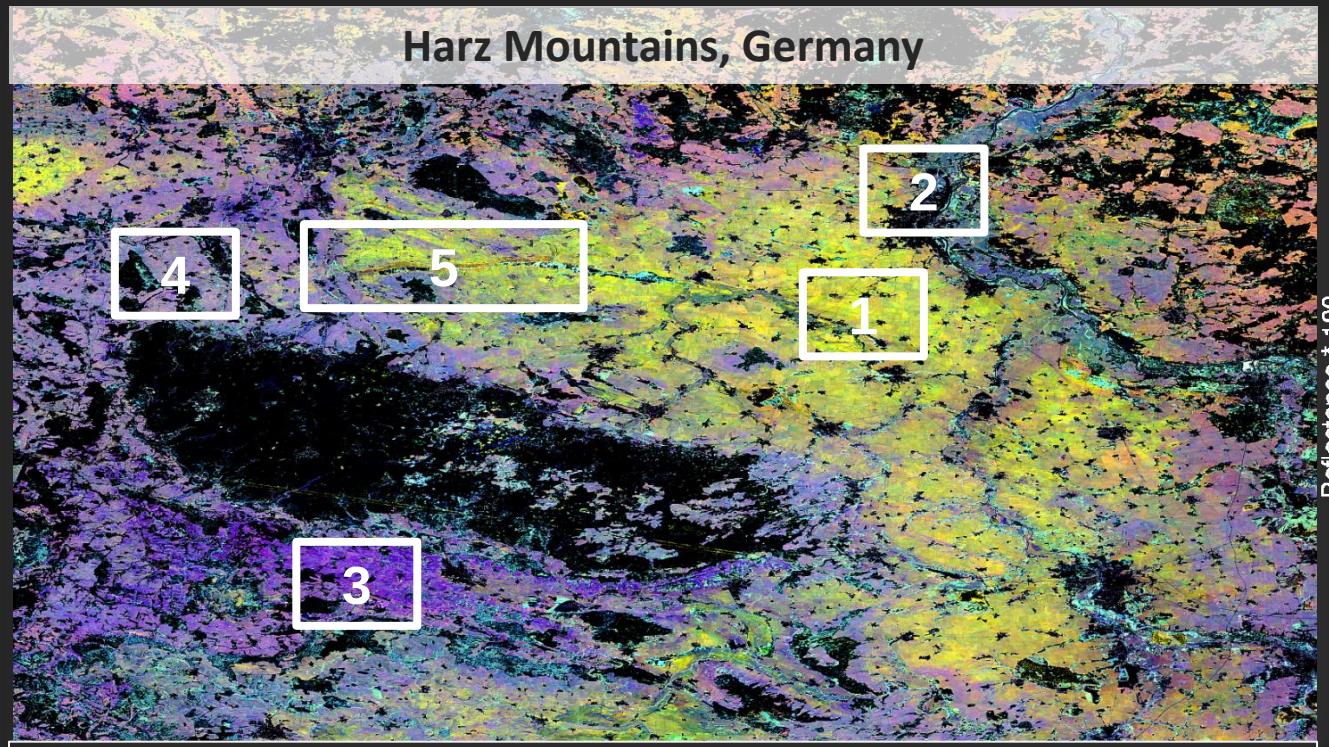
Substitution of thresholds

- T2 PV_{max} substitution
- based on the World Settlement Footprint (WSF) developed by DLR (Marconcini et al. 2019)
- Available globally from 1984 until today

Marconcini, M., Gorelick, N., Metz-Marconcini, A., and Esch, T. (2019). Accurately monitoring urbanization at global scale – the world settlement footprint. World Bank Land and Poverty Conference 2019, March 25-29, 2019.

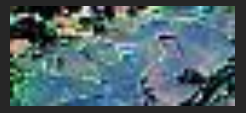
Potential Application

Covariates for digital soil mapping + derivation of soil constituents

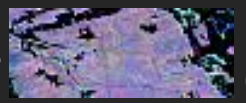


Soil units World Reference Base (WRB) - Examples

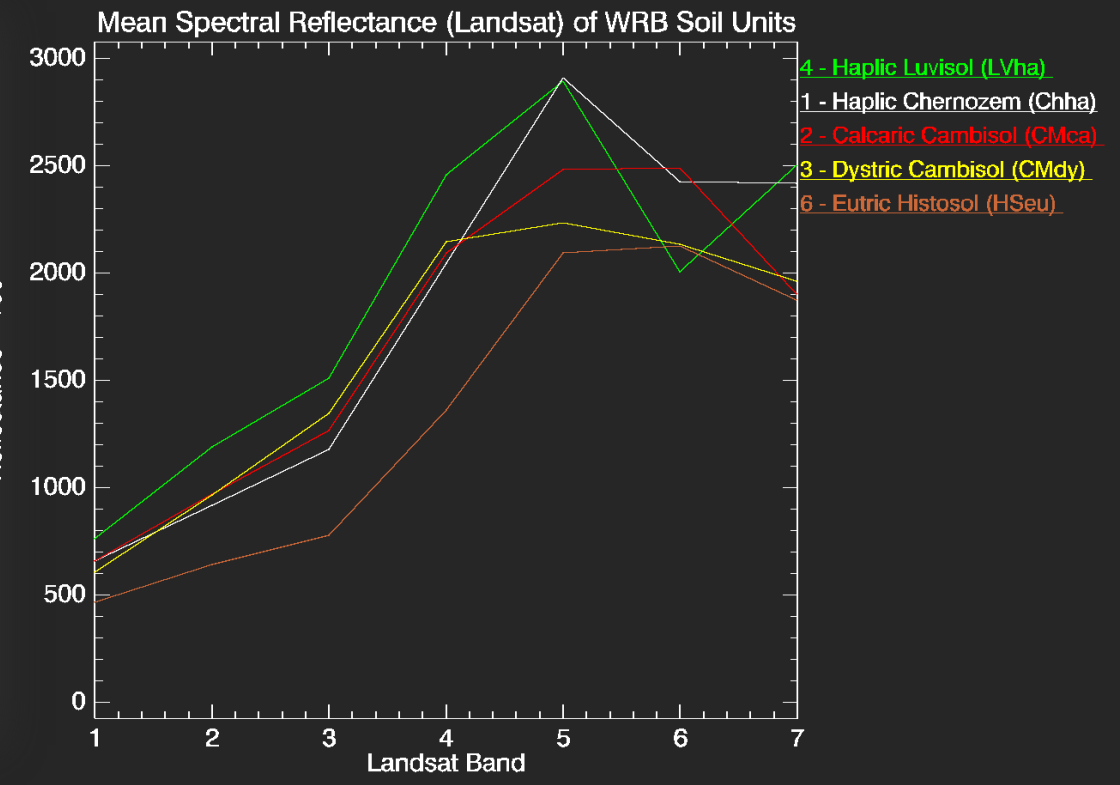
1  Haplic Chernozem (Chha)

2  Calcaric Cambisol (CMca)

3  Dystric Cambisol (CMdy)

4  Haplic Luvisol (LVha)

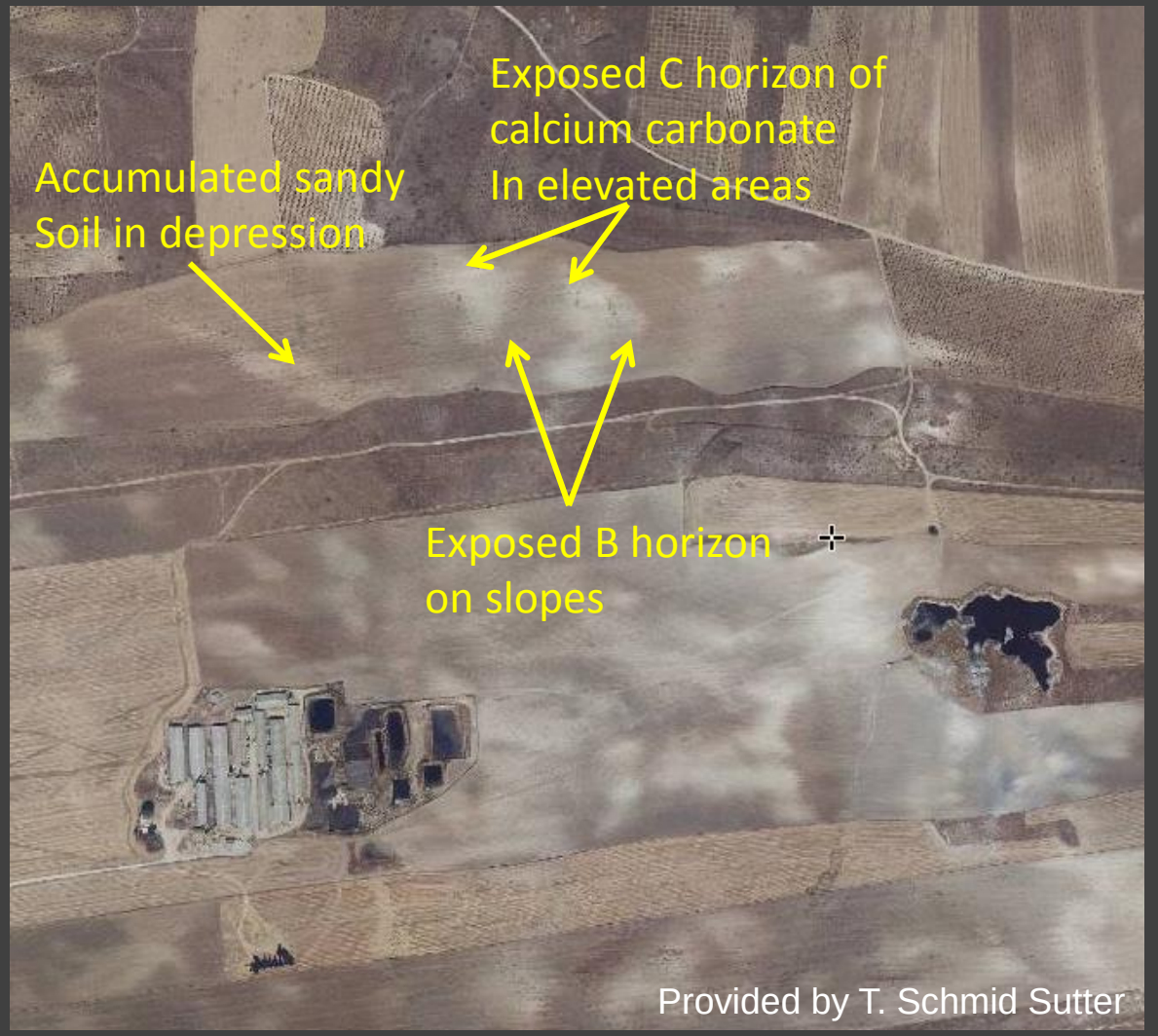
5  Eutric Histosol (HSeu)



Potential Application

Spatial variability of soils

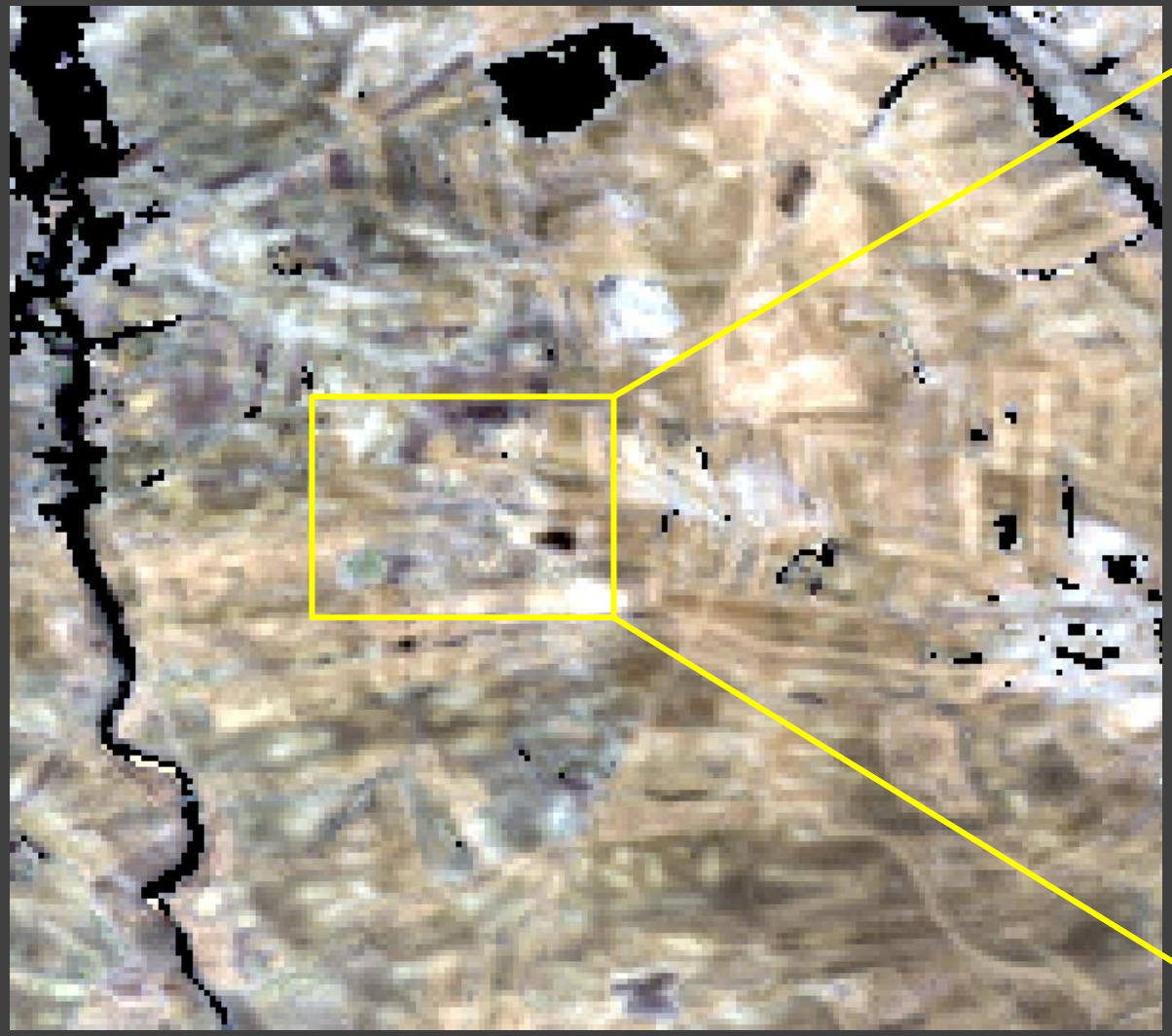
High resolution EO Data
Loss of A and B horizons due to erosion in Spain



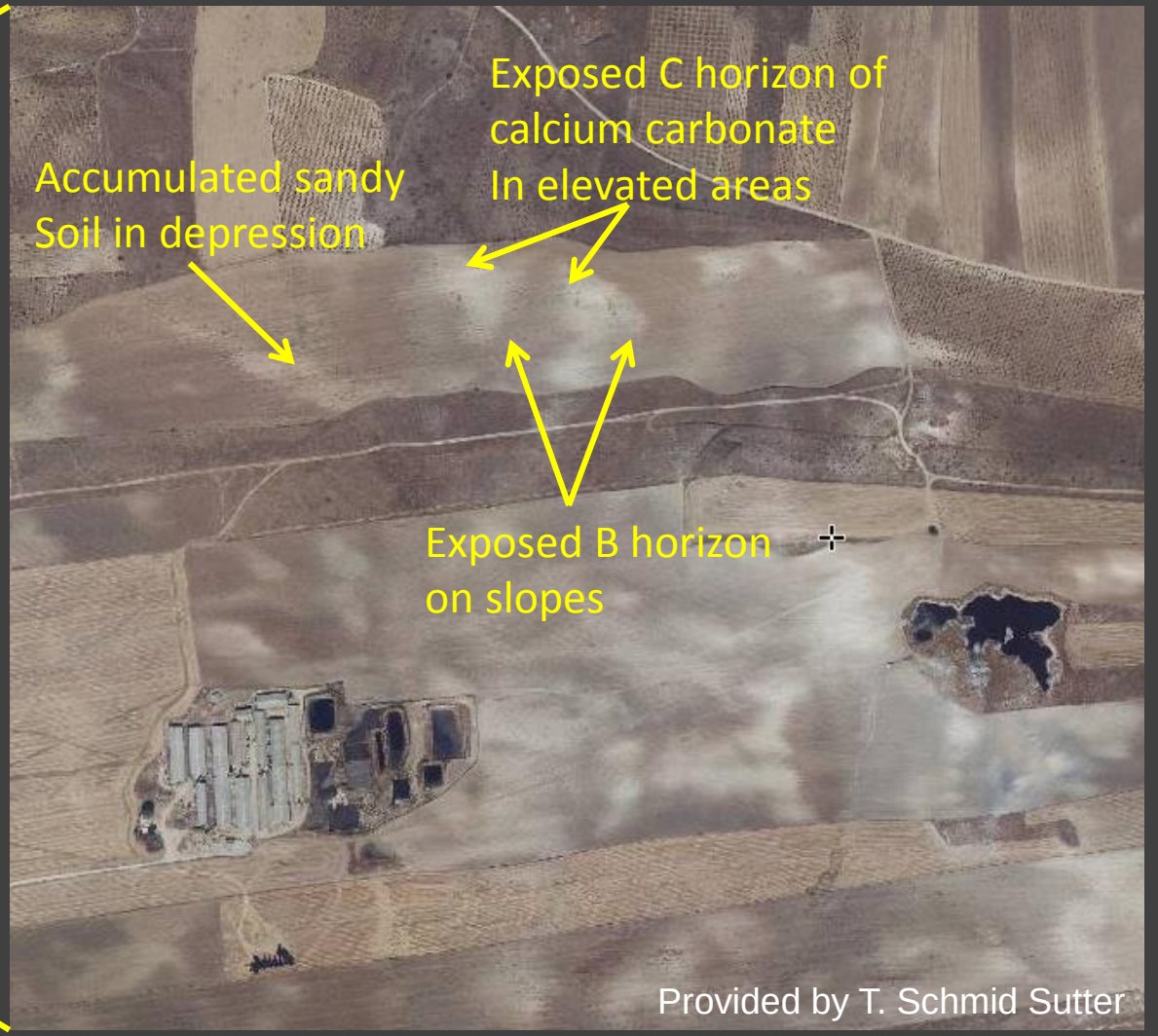
Potential Application

Spatial variability of soils

Landsat
Exposed Soil Composite (2000 – 2004; RGB 3-2-1)



High resolution EO Data
Loss of A and B horizons due to erosion in Spain



Potential Application

Spatial variability of soils

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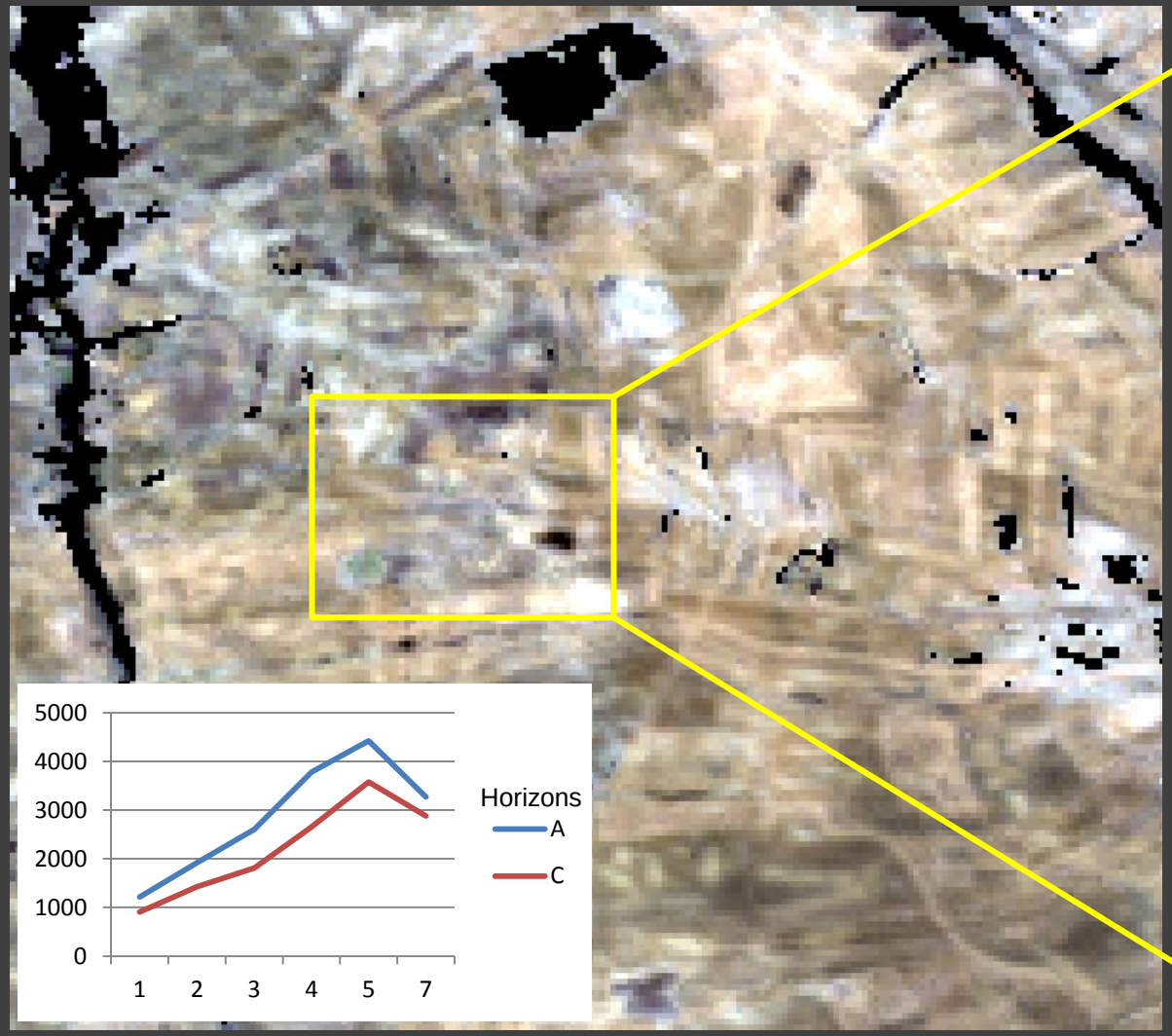
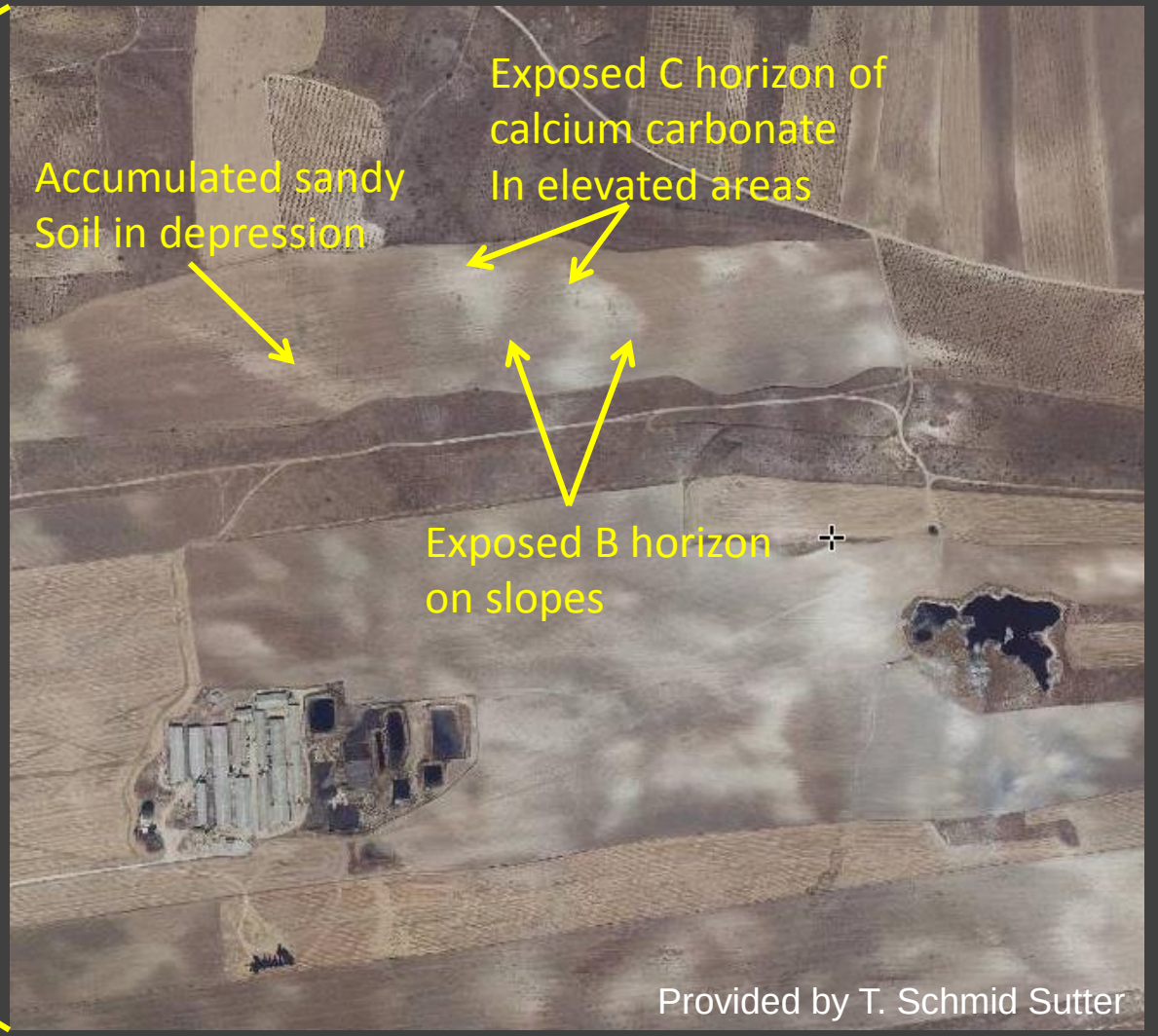


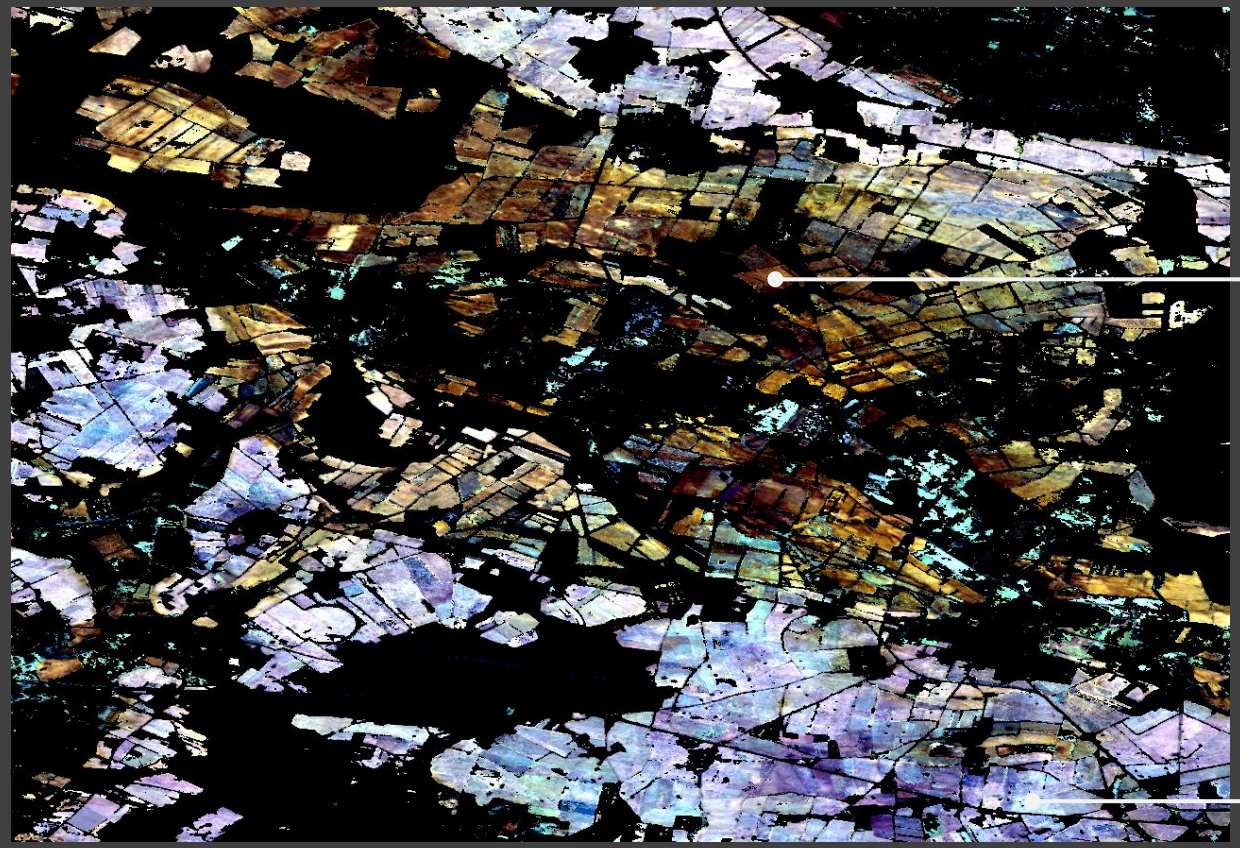
High resolution EO Data
Loss of A and B horizons due to erosion in Spain

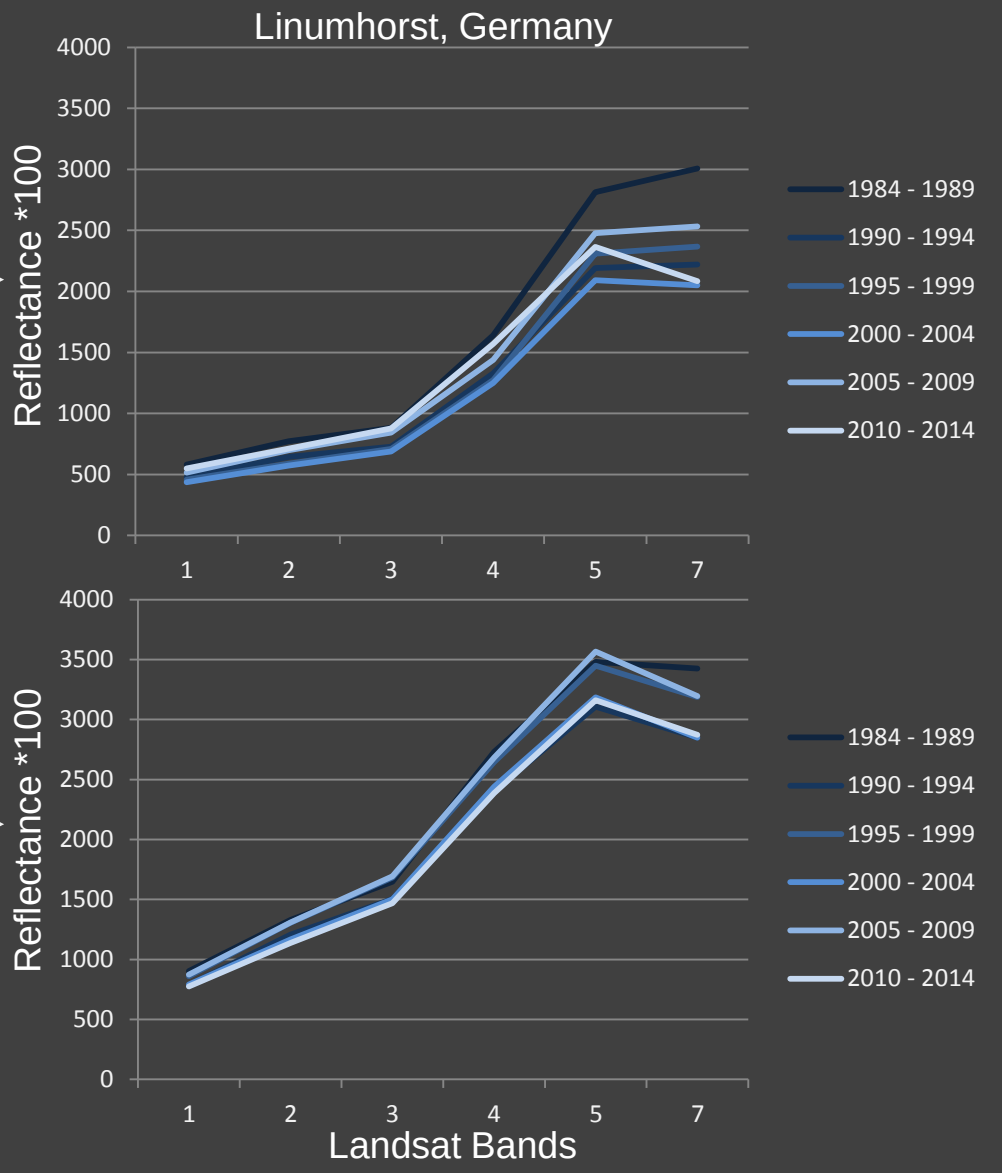


Potential Application

Temporal variability of soils

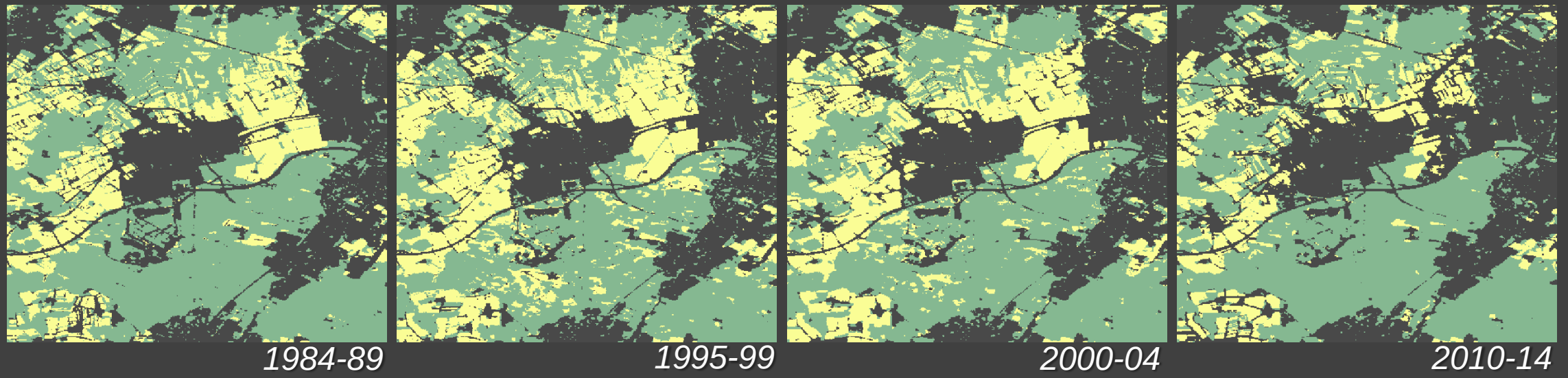
Linumhorst, Germany
Soil Reflectance Composite 2010 – 2014 (RGB 7 – 5 – 3 Landsat Bands)





Potential Application

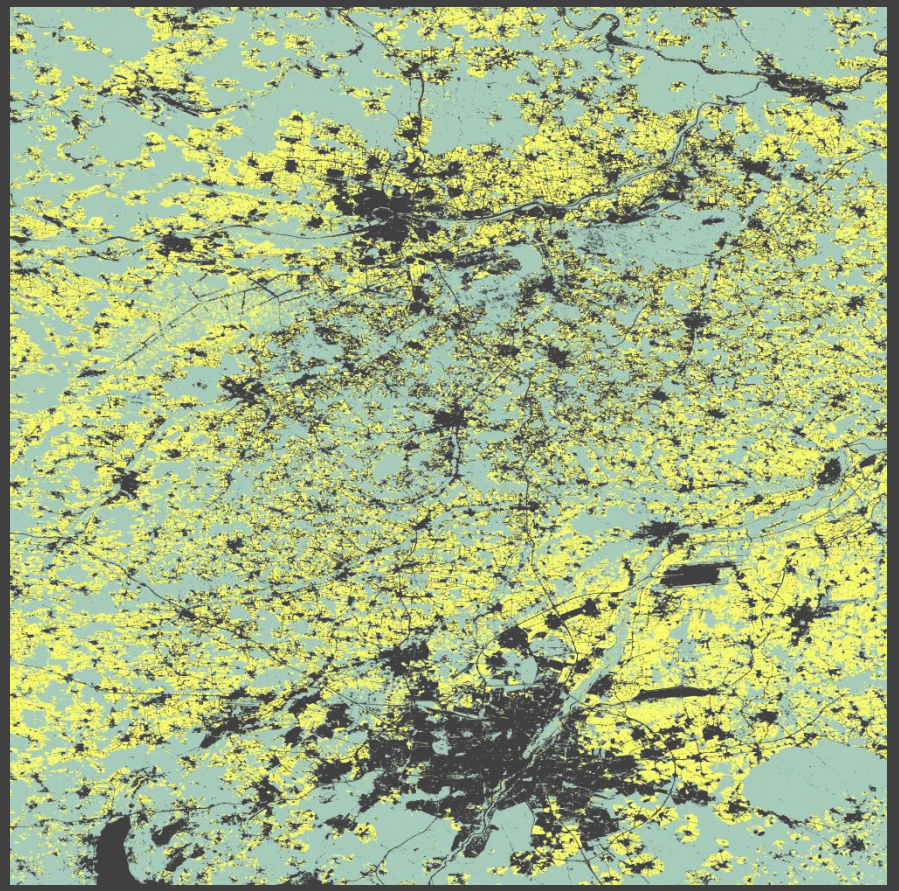
Exposed soil coverage and simple landcover change



exposed soils | permanent vegetation | permanent non-vegetation

Potential Application

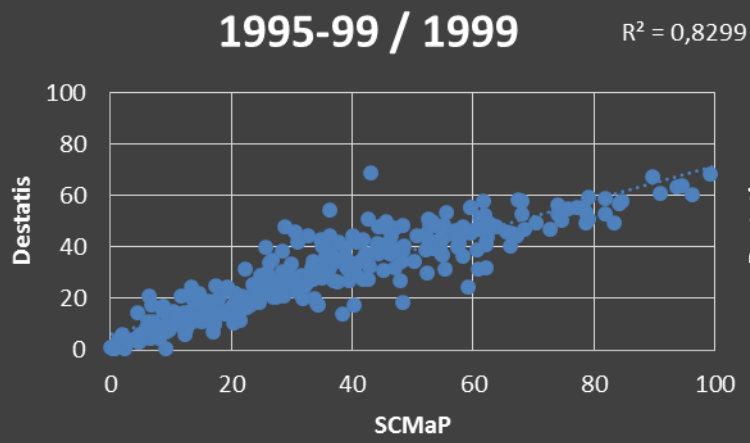
Exposed soil coverage and simple landcover change - Validation

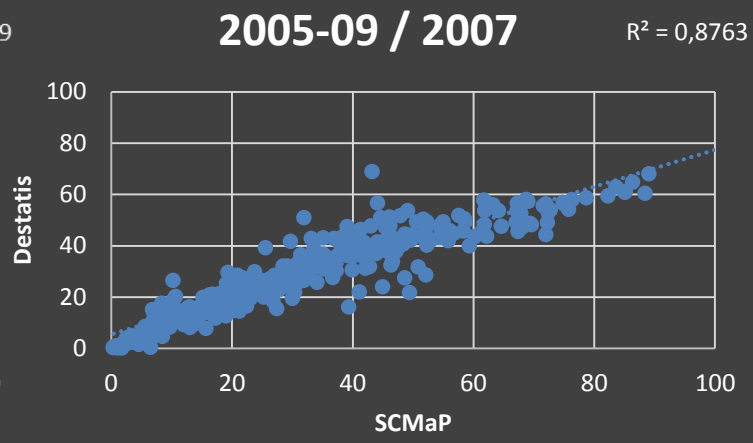


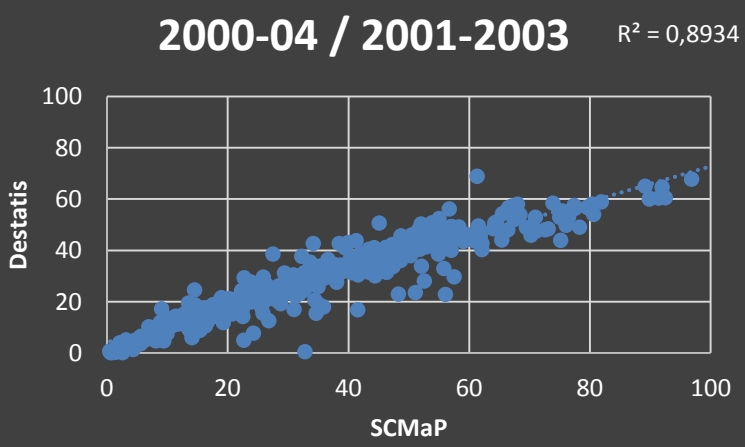
Soil Exposure

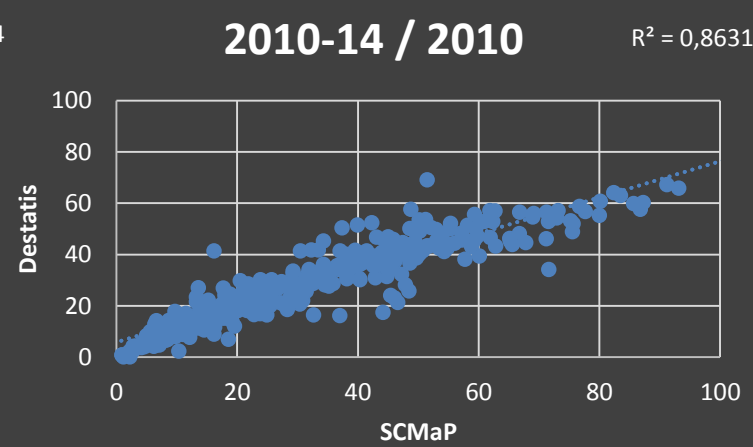
Permanent Non-vegetation

Permanent Vegetation

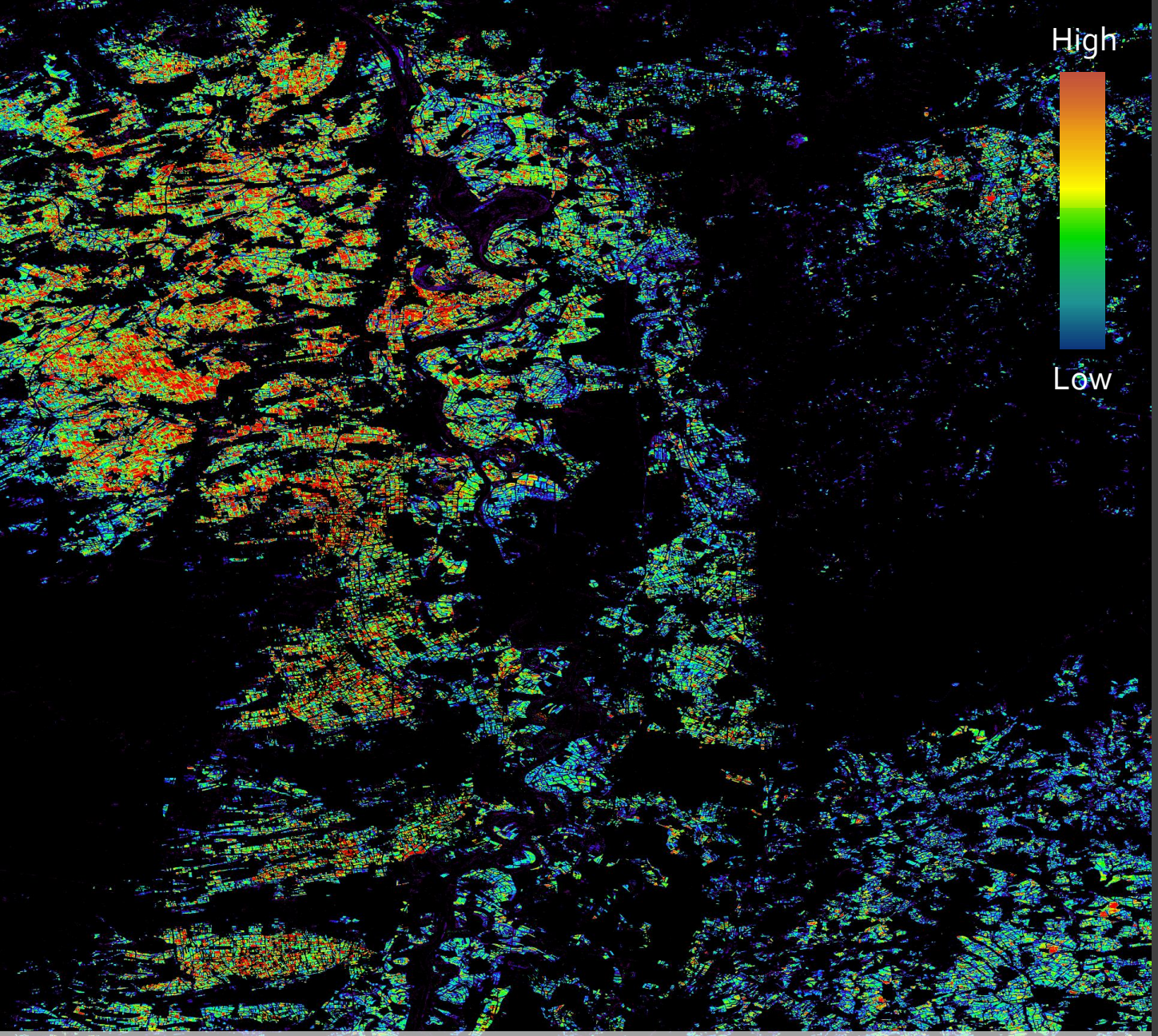








- Statistical Data from DESTATIS (German Federal Statistical Office)
- Exclusion of permanent grassland)
- 1999, 2001, 2003, 2007, 2010
- Comparison on county level



Vineyard area, Germany

Potential Application

Soil exposure frequency – erosion potential

Soil Exposure frequency [%]

- Percentage of time a soil is exposed
- Areas prone to soil erosion
- Agricultural active areas only
- 5-year time periods:

1984 - 1989
1990 - 1994
1995 - 1999
2000 - 2004
2005 - 2009
2010 - 2014

Outlook and Recommendation

Outlook

- SCMaP – fully automated processor
- Products suite - main product = soil reflectance composites
- Challenges:
  - Thresholds (soil exposure)
  - Compositing (Data density)

In Development:

- Sentinel 2 for continuation of data provision
- Multispectral data base L8 / S2 – Harmonized (HLS)
- Substitution of Tresholds
- Looking for partners to explore the SCMaP Products for soil mapping and monitoring

Outlook and Recommendation

Recommendation

<u>Answer questions:</u>

Who are the main users/stakeholder?

What are the most important (essential) L3/L4 EO products that are urgently needed for soil monitoring?

Pushing imaging spectroscopy constellations until we get CHIME (ISS: DESIS, HISUI, EMIT; PRISMA, EnMAP, SBG)

Thank you for your attention!

German Aerospace Center (DLR)

uta.heiden@dlr.de

simone.zepp@dlr.de

marianne.jilge@dlr.de